ECONOMIC BOTANY

Devoted to Applied Botany and Plant Utilization

Vol. 7 APRIL–JUNE, 1953 No. 2

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Book Reviews

American Weeds. Plants, Man and Life. The Mighty Leaf—Tobacco Through the Centuries.

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The Drug Aloes of Commerce, with Special Reference to the Cape Species

The laxative property in the juice of aloe leaves has been recognized since ancient times. The Union of South Africa is the principal producer today, but 90% of American imports come from the Dutch West Indies—Aruba and Bonaire.

W. H. HODGE [1]

Historical Introduction

Aloes are natives of the Old World, being primarily African. They have been known and used medicinally since antiquity. The laxative property (attributable to a pentoside, aloin) of the bitter resinous juice in the leaves of these succulents was appreciated by the Greeks at least as early as the fourth century B.C. Celsus, Dioscorides and Pliny were familiar with certain of these plants, and it is said that Aristotle, himself, persuaded Alexander the Great to conquer the island of Socotra, a primary source of choice drug aloes. Socotra, lying in the Arabian Sea about 200 kilometers from the easternmost extension of the African continent, is now a British possession and still remains a producer of apparently the most valued of the three chief commercial types of drug aloe, namely, Socotrine (or Zanzibar) aloe, which is obtained from the native species, *Aloe perryi* Baker. Medicinally speaking, the action of Socotrine aloe is said to be milder and less irritating than that of the other drug aloes. In this respect West Indian aloe ranks second, Cape aloe third.

A second species, *Aloe barbadensis* Miller, is the source of so-called Barbados, Curaçao or West Indian aloe. This species has been cited widely but incorrectly under the binomials *Aloe vera* and *Aloe vulgaris*, but these are synonyms, as has been pointed out by Hill (7). The common names just mentioned are misnomers. New World drug aloe is obtained from a plant which, though grown commercially mainly in this hemisphere, is not an American species but a native of the Old World where it was probably the first species to have been used medicinally, at least by Europeans. Yet its exact center of origin in the Old World is still unknown. It is most frequently stated to be from the "Mediterranean region" (*e.g.*, southern Spain, Sicily, Greece, North Africa) or, occasionally, as "from the Cape Verde and Canary Islands". In all this region *A. barbadensis* is widespread, yet it appears to grow not wild but as a naturalized plant or horticultural escape. Chevalier confirms this in his account of the flora of the Cape Verde Islands (3). He suggests that the homeland of this species may be discovered eventually somewhere along the African coast near the southern end of the Red Sea, an area bordering upon Ethiopia. *A. barbadensis* is known from Ethiopia, but whether it is an immigrant or native is still uncertain. If such a homeland exists astride the ancient trade routes, it would be easy to account for the present distribution of this species in the Mediterranean region and in southern Asia as well.

[1] Division of Plant Exploration and Introduction, United States Department of Agriculture, Plant Industry Station, Beltsville, Md. All photographs by the author unless credited otherwise.

Because of its medicinal properties, *A. barbadensis* was introduced into the New World very early, probably in the sixteenth century. The letter of Dr. Diego Alvarez Chanca, dated 1494, relating to the second voyage of Columbus to America, mentions "aloes" as growing on Hispaniola. Chanca writes: "there are aloes too, though not of the same kind as those we are acquainted with in Spain, but nevertheless a species of aloes that we doctors use". Chanca was confusing some native American plant, probably one of the West Indian species of *Agave*, with the medicinal aloe of Spain, namely *Aloe barbadensis*. Even today, in many parts of the Old World, where they have been introduced, agaves

FIG. 1. Typical aloe country in the Cape Province, South Africa. Rocky banks of the Gouritz River near Albertinia, one of the classic localities for *Aloe ferox*, colonies of which are along the ridge at the right.

are called " American aloes " because of their similar growth habit. Today *A. barbadensis* may be found naturalized in many of the more arid areas bordering upon the Caribbean not only throughout the West Indies but also in such continental countries as Venezuela and Mexico, especially central Mexico and Lower California where aloes are often to be found persisting around sites of the old missions. Moreover the writer has noted plants established as far afield as Andean Peru (near Ayacucho).

Wherever it has been naturalized this species often has become a dooryard plant, serving as an ever-present garden " medicine chest ". For example, natives in the Caribbean area consider *A. barbadensis* to be a sovereign specific for all minor cuts, and the fresh juice of the

FIG. 2. Characteristic plants of *Aloe ferox*, showing arborescent habit. Photographed in the Little Karroo, between Amalienstein and Calitzdorp, Cape Province.

leaves is used as a substitute for iodine. It is also reported that in the Dominican Republic the leaf pulp of this aloe, mixed with rum and honey, is employed as a cold remedy. More recently the juicy leaf pulp has served medicine as an effective agent in the treatment of X-ray burns.

FIG. 3. Closeup of a single flowering plant of *Aloe ferox*. The flowers are scarlet. Note coarse leaves with heavy surface spines which permit conical stacking of the leaves after harvesting.

The island of Barbados was occupied soon after the Discovery, and aloes were cultivated there in the centuries that followed, mention having been made of them by Ligon, an early historian, who visited the island in 1647 (4). Plants brought from Barbados in 1696 were grown in English gardens, and it was upon such horticultural material from the "Islands of America" that Miller based his description of *A. barbadensis*. Today the drug aloe industry of Barba-

dos, formerly of considerable importance, has virtually disappeared, having been supplanted in more recent years by the aloe production of the islands of Aruba and Bonaire together with that of the neighboring arid coast of Venezuela, particularly around Coro, in the State of Falcón. Inasmuch as little or no bitter aloe originates today on Barbados, it seems wiser to use the more general name, " West Indian Aloe ", to designate the crude drug obtained from the Caribbean area. This is the more logical when it is realized that the name " Curaçao Aloe " was applied merely because that island has been the center of export of drug aloes. Actually no aloes have ever been produced on Curaçao but only on neighboring Aruba and Bonaire.

FIG. 4. Harvesting leaves of *Aloe ferox* near Albertinia. Note sickle-like tool used by the worker.

The crude drug produced in the Dutch

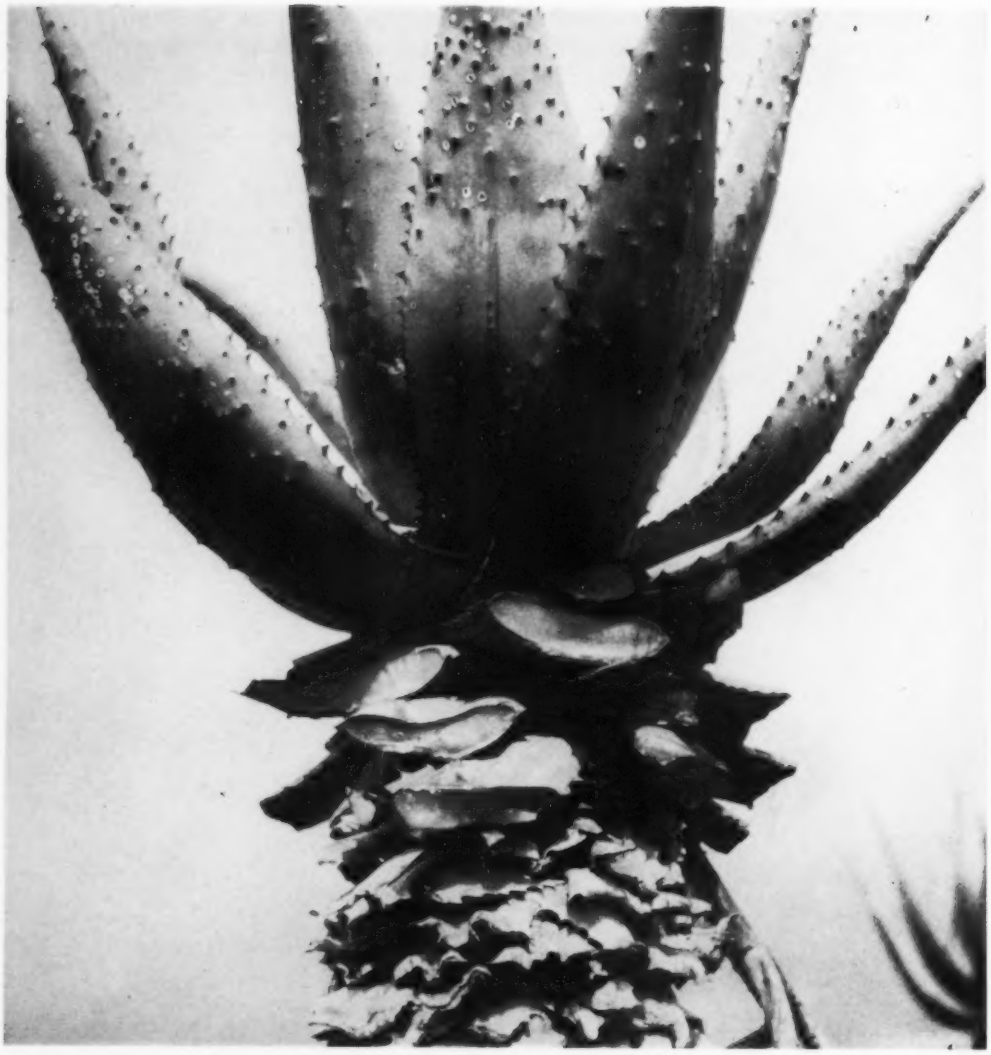

FIG. 5. A plant of *Aloe ferox* as it appears after leaf removal. Only the older lower leaves are cut for their juice. The dried leaf bases remaining from previous years' cuttings may be seen below. Yellow aloetic juice exudes chiefly from that part of the mesophyll lying between the narrow outer (darker) chlorenchyma and the lighter and thicker storage parenchyma within.

islands and in Venezuela may pass in the trade as Barbados Aloe, but it has been called more often "West Indian Aloe" or "Curaçao Aloe". Although the aloin content may vary considerably in the several aloe-growing regions of the Caribbean, all drug aloe produced in that area is derived from a single species, *A. barbadensis*[2]. This is in spite of the

[2] As an aid in reaching this conclusion the writer has examined representative herbarium material of *A. barbadensis* from Venezuela and Aruba. These specimens are located in the herbarium of the United States National Arboretum. Flowering material from Aruba was transmitted through the courtesy of Mr. C. H. G. Eman of the Aruba Aloe Products Company.

fact that herbarium material supposedly representing drug aloe plants originating from Curaçao was identified some 50 years ago by J. G. Baker as *Aloe chinensis* (2), a species raised by him from varietal rank in 1877 [3]. In 1819 this taxonomic entity was first described as a variety of *A. barbadensis* by Haworth [4], a horticulturist, who based his description on living hothouse plants introduced from " China " in 1817 by a Mr. William Anderson. The plant is certainly not native to China [5], but its country of origin, most likely northeastern Africa, is still unknown. Actually the differences described and used for separating *A. barbadensis* and *A. chinensis* are minor, and the present writer feels that the latter species might better be treated as a form of *A. barbadensis*. According to Baker's original description, *Aloe chinensis* possesses shorter whitish-blotched leaves, a laxer raceme and shorter stamens. Plants grown in Aruba and Bonaire today do not fit this description. Concerning variation within a species, one contemporary student of this genus has had this to say (10): " In the wild state, and in their various geographical stations aloes vary considerably in size, length and width of leaf, leaf markings, racemes, length of pedicels and flowers, while plants grown in gardens and greenhouses, under conditions very different from their natural habitats, frequently modify out of all recognition ".

Aloe ferox Miller, source of the Cape Aloe of South Africa, is the remaining member of the trio of important drug-producing species. Unlike the other commercially important aloes just discussed, this arborescent species is very distinct, belonging to quite a different section (Pachydendron) of the genus. The writer became interested in this species while searching in South Africa during 1951 for possible plant sources of the drug, cortisone. Chemical assay of the leaves of *Aloe ferox*, one of the many plants investigated in this cortisone program, yielded negative results. It will be the main subject of this article.

[3] Bot. Mag. 103 (1877), plate 6301.

[4] Haworth Suppl. Pl. Succul. (1819) 45.

[5] Forbes and Hemsley, in their enumeration of the plants of China (1903), state that this species is not native to that country.

FIG. 6. A Cape aloe worker of Albertinia. Crude skin mittens and apron protect him against the exuding juice of the fresh cut leaves.

Nomenclature in the Drug Aloes

Because of the confusion in nomenclature and certain inaccuracies in the botanical descriptions that have existed so long in the literature of the principal economic species of aloes, it may be of value to include here not only a key to the three species mentioned but also a synopsis of their essential synonymy:

Key to the Principal Drug-Producing Aloes

Stem well developed (usually 2–3 m. or more high); leaves 10–15 cm. broad at base, spiny on margins and surfaces; inflorescence with 5–8 branches; flowers 35–40 mm. long, vivid scarlet or (occasionally) orange.
Aloe ferox (Cape Aloe)

Stem poorly developed (usually less than 0.5 m. high); leaves 5–8 cm. broad, spiny only on margins; inflorescence simple or with few branches; flowers about 25–30 mm. long, not vivid scarlet nor orange.

Leaves 5–6 cm. wide; flowers bright red with green-tipped segments when young, turning yellow at maturity; segments of limb much shorter than the tube.
Aloe perryi (Socotrine Aloe)

Leaves about 7.5 cm. wide; flowers yellow at all stages with segments of limb approximately equalling the tube.
Aloe barbadensis (West Indian Aloe)

Synonymy of the Principal Drug-Producing Aloes [6]

Aloe barbadensis Miller Gard. Dict., ed. 8 (1768) no. 2.

Aloe perfoliata L. [var.] π *vera* Linnaeus Sp. Pl. (1753) 320.
Aloe vera "L." of many authors, not Miller (1768).
Aloe vulgaris Lamarck Encycl. 1 (1783) 86.
Aloe chinensis Baker? in Bot. Mag. 103 (1877) plate 6301.

Aloe ferox Miller Gard. Dict., ed. 8 (1768) no. 22, excl. syn. Munt.

Aloe perfoliata L. [var.] γ Linnaeus Sp. Pl. (1753) 320.
Aloe perfoliata L. [var.] ϵ Linnaeus *loc. cit.*
Aloe socotorina Masson in Trans. Roy. Soc. Lond. 66 (1773) 1, 287.
Aloe perfoliata Thunberg Diss. 1 (1785) 6.
Aloe perfoliata L. [var] θ *ferox* Aiton Hort. Kew. 1 (1789) 467.
Aloe perfoliata L. [var.] ζ Willdenow Sp. Pl. (1799) 186.
Aloe supralaevis Haworth in Trans. Linn. Soc. 7 (1904) 22.
Aloe pseudo-ferox Salm Dyck Cat. rais. (1817) 31, 61.
Pachidendron supralaeve Haworth Revis. (1821) 38.
Pachidendron ferox Haworth *loc. cit.*
Pachidendron pseudo-ferox Haworth *loc. cit.*
Aloe subferox Sprengel Syst. 2 (1826) 73.

Aloe perryi Baker in Jour. Linn. Soc. 18 (1881) 161.

Aloe succotrina of many authors, not Lamarck (1783).

[6] The synonymy for *A. barbadensis* is taken mainly from Hill (7), while that of *A. ferox* is from Reynolds (10).

Cape Aloe Industry of South Africa

Geographical Distribution of the Cape Aloe. *Aloe ferox*, sole source of the Cape Aloe of commerce, is one of the commonest and probably the best known of the 132 species of this genus recorded as native to South Africa. Indeed it is such a conspicuous plant on much of the rocky veld country of the Cape Province that it has been mentioned as a fitting candidate for the national flower. Reynolds (10), who has given the most recent and fullest description of this species, delimits its range as running roughly some 600 miles from the Breede River, near Swellendam, to the Umtamvuna River which is the natural boundary between Cape Province and Natal. *Aloe ferox* extends inland into that part of the Karroo occupied by the Cape Ranges with their dry river beds, shallow soils and rock-exposed surfaces.

Although very abundant where it occurs, the distribution of the species within its over-all range is spotty, a fact to be expected of a plant inhabiting montane terrain with its variety of microclimates. Generally speaking the species occurs in a vegetational type recognized as "succulent bushland", and where this is found *A. ferox* is often, at

Fig. 7 (*Upper*). In preparation for gathering the juice, a shallow depression has been scooped in the ground, and over this the worker is placing a skin which will serve to catch the draining juice. Albertinia, Cape Province.

Fig. 8 (*Lower*). Fresh-cut leaves are placed around the margins of the skin. Albertinia, Cape Province.

least locally, one of the dominant plants. It is particularly abundant on arid rocky hillsides. On such situations, ranging from sea-level to 915 m. elevation, the midwinter (July–August) frosts are

Fig. 9. A completed pile of leaves stands about waist high. The juice drains down from the cut butt ends onto the skin shown in the two preceding figures. Albertinia, Cape Province.

much reduced in frequency; annual rainfall runs from 5–30 cm.; while the mean temperature range is 27°–31° C (1).

Description of Plant. Under these environmental conditions *A. ferox* is usually an arborescent plant, sometimes up to five meters tall. The stout stem is crowned by a dense rosette of rather thick fleshy leaves, up to a meter long, and amply armed with regularly spaced marginal teeth and often, on the surfaces, with stout scattered spines. Surface spininess is characteristic of the species at the westernmost limits of its range in the drug aloe localities, whereas

elsewhere the leaf surfaces, except in young plants, are usually unarmed save for a few dorsal spines along the median line. The old leaves persist as they dry, forming " skirts " on the stems of the erect racemes of showy scarlet to orange flowers, appears from May to October. In the latest edition of L. H. Bailey's " Manual of cultivated plants ", as well as in his " Cyclopaedia of Horticulture ",

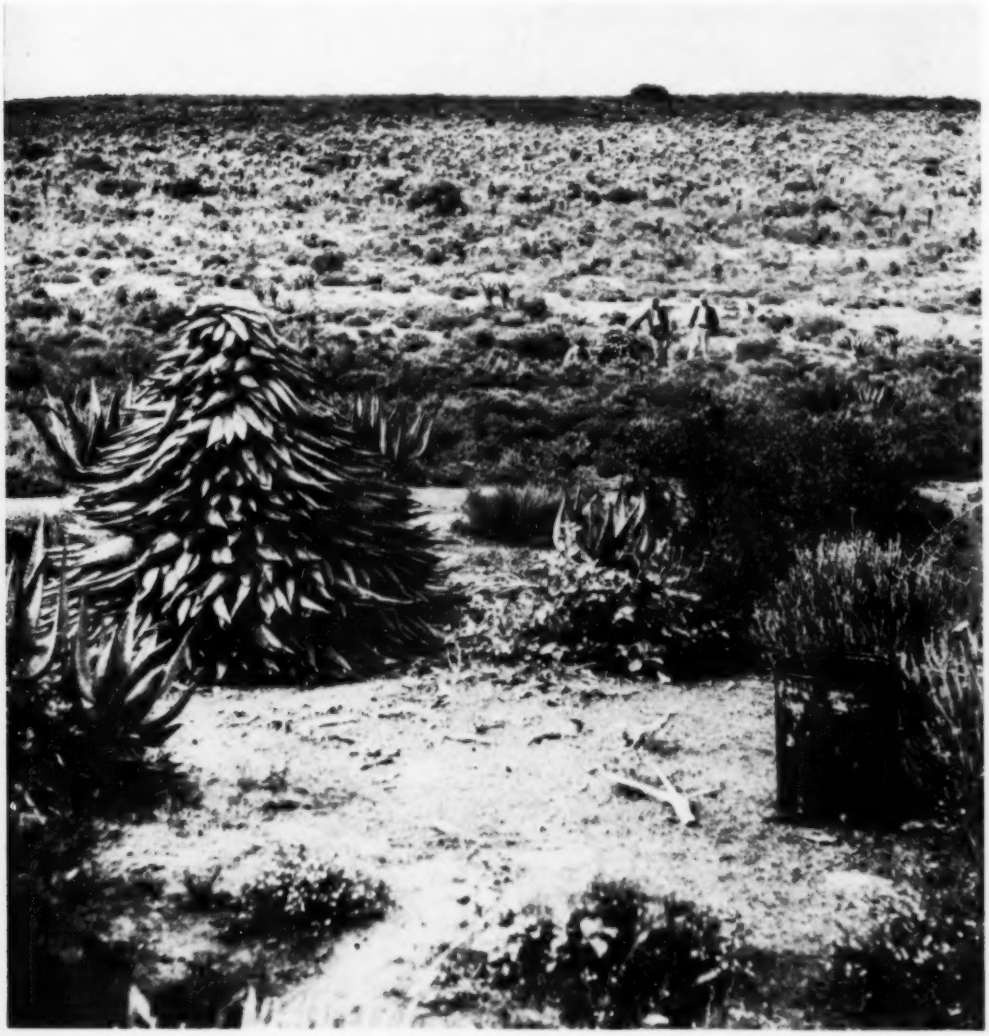

FIG. 10. General view of the harvesting of aloe leaves near Albertinia. Several piles of draining leaves have already been set up. The tin in the foreground will be used for collecting the juice. Plants of *Aloe ferox* dot the terrain.

plants. This characteristic is not shown in early figures of the species where the stem, apart from the crown, is illustrated as quite devoid of leaves. The inflorescence, a branched panicle with several

the flowers of *A. ferox* are described incorrectly as " greenish-yellow ". On the other hand, the U. S. Dispensatory, 22nd Ed., states that the flowers are " striped whitish ". These errors apparently stem

from the colored plate illustrating Sim's description of horticultural material of *A. ferox* grown in England [Curtis's Botanical Magazine (1818) plate 1975]. The color of the flowers illustrated is certainly atypical and is not characteristic of wild plants in South Africa. The

FIG. 11. *Aloe barbadensis* growing at Aruba, N. W. I. The plants are acaulescent and the flowers yellow. This species is the source of all drug aloe produced in the Caribbean region. (*Courtesy C. H. G. Eman*).

vivid scarlet hue is well shown in the beautiful color plate of this species reproduced in the monograph by Reynolds (10), as well as in the colored illustration of this species on the cover of the February, 1952, issue of "Natural History", published by the American Museum of Natural History in New York. According to Reynolds, the exact flowering date is dependent upon whether the individual plant is located in a warmer coastal site (early flowering) or a colder interior site (later flowering). When grown as an ornamental north of the equator in southern California, this species usually flowers during February and March.

Compared with the other two drug-yielding aloes, *A. ferox* is a relative newcomer to commerce, not having been known before the time of the pioneer voyages which touched at the southern tip of Africa during the fifteenth and sixteenth centuries. However, its conspicuous colonies may have been seen by even the earliest European voyagers, some of whom, like Bartholomew Diaz and Vasco da Gama, touched at Mossel Bay (then called "Agoada de San Bras") where this species is abundant, growing fairly close to the Indian Ocean.

Early History. *Aloe ferox* was cultivated in England by Miller in 1759 (12), and upon this material was based his original description of the species published in 1768. Cape aloes, in drug form, were first exported in 1761 (6) but are said to have appeared in London pharmaceutical houses for the first time in 1780 (16), a few years after the gathering and preparation of the crude botanical product had been observed in the field by Thunberg (14) and soon afterwards by Sparrman (13).

Just what caused the selection of this species originally as a source of bitter aloes at the Cape is not clear, for *A. ferox* is quite different in habit from the then known drug species, the two mentioned earlier in this paper. The best assumption is that of all the native aloes that might have been utilized easily from the economic standpoint [7], *A. ferox*, with

[7] No real systematic study appears to have been made of the comparative drug-yielding merits or qualities of the numerous species of aloes apart from the trio mentioned in this paper. Yet the genus is a large one with more than 200 species in Africa. It would not be

its large leaves, occurred in the greatest numbers and by chance in the area (between Swellendam and Mossel Bay) which was nearest to Capetown, the first center of European colonization in South Africa.

According to Sparrman's account, the

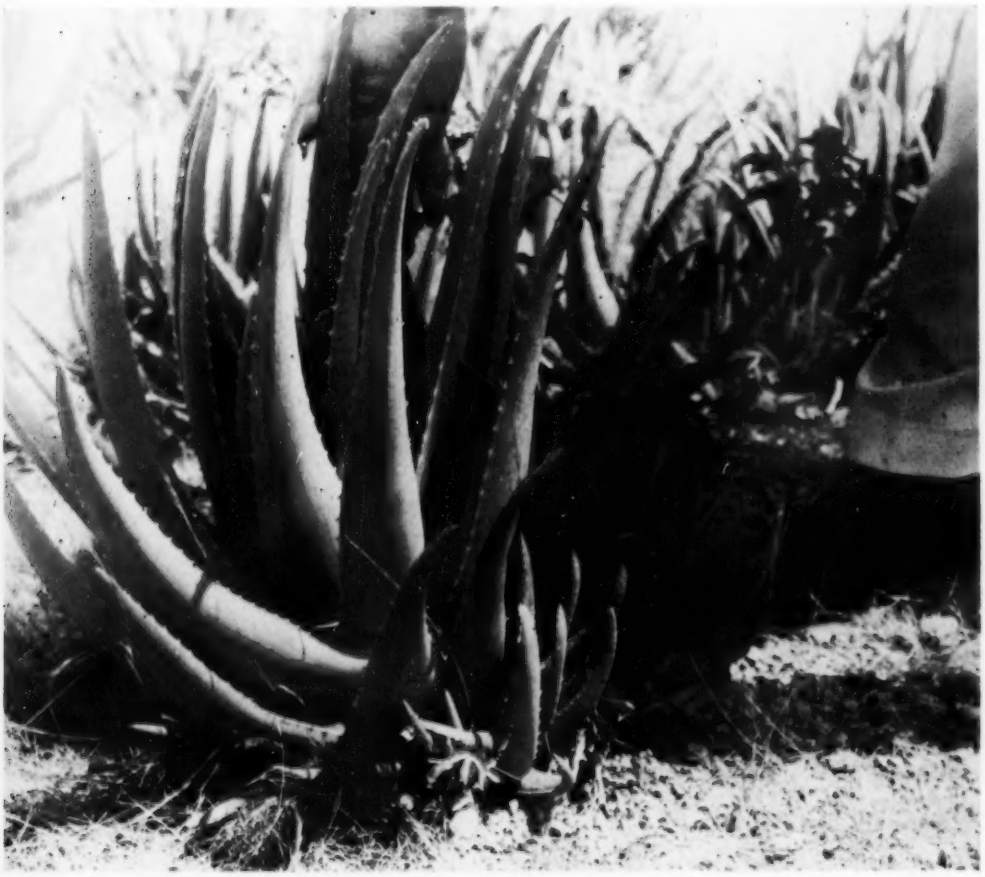

FIG. 12. *Aloe barbadensis* at Aruba, showing relative size. Note that the spines are limited to the leaf margins. The suckers or offshoots, seen at the base of the adult plant, are used for replanting and require about three years to reach maturity. (*Aruba Esso News Photo*).

use, value, and preparation of "gum aloe" was known to the natives of the Cape region long before it was brought to the attention of the European colonists. From this, one might infer that *A. ferox* was recognized and used as a drug plant in pre-colonial times. To quote Sparrman:

"Both the use, and the real name of this vegetable (viz. aloe) was, as many people have told me, long unknown to the colonists, and on this account the plant had been neglected and held very cheap by them. It is true, there had always been in the government service a number of negro slaves, who, at their native place, which was another part of the African coast, had acquired the method of preparing, as well as to know

unreasonable to suppose that among such an assemblage, other species, not yet investigated, might prove to be even better sources of drug aloe.

FIG. 13. Inflorescence of *Aloe barbadensis*, flowering at Aruba in February. Natural size. (*B. P. I. photo*).

the value of the gum aloe; but bowing, under the yoke of slavery as they did, they would rather at any time have seen a dart pierce the hearts of their tyrants, than be serviceable in procuring them any additional knowledge or source of wealth of any kind; by which, on the one hand, the avarice, pride, and power of their masters, and on the other, their work, as well as the number of slaves needed would be increased. For this cause, the use of the aloe was for a long time a secret among the slaves; who, indeed, made it a point of conscience not to reveal it, till one of them, called Goree, made a discovery of it to a colonist of the DeWitt family. Whether this was the effect of gratitude to his master for his humane treatment of him, or whether it was done in the expectation of being rewarded for it, they could not inform me with any degree of certainty: they only knew that DeWitt had, by means of this discovery, obtained an exclusive privilege for the delivery of a fixed quantity of aloes to the East-India Company, and had entrusted Goree with the inspection of the whole work. It is likewise from the name of this negro, that the aloe plant is to this day generally, if not always, called the Goree-bosch in Africa ".

The aloe plants to which Sparrman refers were growing, as he says: " most abundantly in the tract of country lying around Muscle-bay (Mossel Bay), Gauritz (Gouritz) and Duyvenhoeks (Duivenhoks) rivers; so that in certain spots about these places, and that principally on the declivity of mountains, these plants formed groves (as it were) of small palm-trees ". A few years previous, on November 13, 1773, Thunberg had passed through the same localities and he observed that: " the whole of this tract produced aloe trees in abundance, which in some places entirely covered the hills and the sides of the mountains, where they appeared at a distance like a numerous army. The trees are of the height of a man, with their stems quite bare below, and a crown at the top of broad, thick and fleshy leaves ".

Many colonies of *A. ferox*, similar to

FIG. 14 (*Upper*). V-shaped type of trough used in draining the leaves of *Aloe barbadensis* on Aruba. The tin at left serves to catch the bitter juice.

FIG. 15 (*Lower*). Fresh aloe juice being brought in from the field by burro, Aruba. (*Aruba Esso News Photos*).

those referred to by these two early travellers, may still be seen today in the same localities cited—lying roughly between Swellendam and Mossel Bay and especially near the communities of Heidelberg (on the Duivenhoks River), Riversdale and Albertinia (near the Gouritz River). Occupying, as they do, rocky non-agricultural land, the colonies of aloes have remained relatively untouched, save as the source of the drug, down through the centuries.

Collection Technique and Preparation. The method of obtaining the crude drug product, Cape aloes, has also been little modified since the 18th century, and Thunberg's description [8] could almost be a 20th century one:

"The mode of preparing it [viz. "gum aloe"] is quite plain and simple. It consists, in the usual phrase of the peasants, in the tapping or drawing off of the juice, and boiling it. The tapping may be performed at all times in the year; but during, and immediately after, the rainy season, the leaves yield a more copious but thinner juice. Those days that are calm and clear, are chiefly selected for the operation of tapping, as windy weather shrinks the leaf, so that less juice is produced, and it hardens too soon. On this work, for the most part, either slaves or Hottentots are employed. A leaf is first cut off, and laid on the bare ground to serve as a channel, upon which several other cut leaves are afterwards placed on each side, with the large end inwards, and over these again others, to the amount of a dozen, or more, so that the juice drips from them into the hollow of the first leaf. The leaves which were cut off not too close to the trunk, were not cut into smaller pieces; as, according to what the farmers asserted, they would not yield the more juice on that account. In this manner several heaps of leaves are laid one after the other, as fast as they can be cut off. When the juice ceases running, the leaves are taken away, and the juice is poured into calabashes, which here, as well as in many other places, are used by the poor as bottles. The greatest quantity of juice that can be thus collected by a man in one day is a large calabash or small pailful. The juice is afterwards boiled down in English iron pots, to such a consistence, that it will not run off a stick that is put into it. All impurities that swim on the top of the liquor are skimmed off in boiling. The juice thus boiled down to one half, is then poured out into wooden boxes, in which it afterwards grows hard. The juice yields generally one third of solid gum, and each box weighs from three to five cwt. each pound of which is sold to foreign nations for three, or four, and sometimes two, stivers".

Today natives still prefer to cut leaves and to boil down the bitter juice during the principal rainy season of August to October, stating that the flow of juice is greater at this time. However, there is always some activity during all except the very driest months. Prior to gathering the leaves, a skin or canvas is spread over a slight depression that is scraped in the ground. The leaves are usually cut in the morning, the cutters using small, often saw-edged, sickles. The bitter yellow juice flows immediately from the cut surfaces, exuding from the immediate vicinity of the fibrovascular bundles which form a ring in the leaf tissue between the superficial chlorenchyma and the large mass of colorless, centrally located, water-storage cells. In nature the presence of a bitter substance in the leaves probably serves as a strong deterrent to hungry animals which otherwise might browse on these evergreen plants.

With their clothing protected against the juice by crude skin aprons, the gath-

[8] Thunberg's original account refers to "aloe socotorina" as the source of the Cape "gum aloes". As indicated earlier, this binomial is a synonym of *A. ferox*.

FIG. 16. The old method of producing drug aloe at Aruba. Fresh juice is inspissated in a copper kettle over a wood fire. (*Aruba Esso News Photo*).

erers place armfuls of cut leaves immediately in a ring around the edge of the skin. The leaves are placed upside down with their butt ends inwards. Successive cuttings of leaves are stacked atop the original ring, and this process continues until a more or less conical pile of bleeding leaves is built up to roughly waist height. The stout spines which characteristically dot the surfaces of the leaves of *A. ferox* in this part of its range keep the leaves from slipping and thus greatly facilitate the making of piles for draining the leaves of their bitter juice. This piling procedure is so traditional and so dependent upon leaf surface spininess that the aloe workers contend that no other of the several local species, all lacking surface spines, could possibly serve as sources of Cape aloe, for "they could not be piled up satisfactorily"[9].

Four to five hours are required for the juice to drain from a pile of leaves, during which time the aloe gatherers usually are busy stacking other leaves. The quantity of juice drained from each pile of leaves is small but is collected into some kind of metal container, often a heavy iron kettle or even a gasoline tin, in which the juice is boiled down until of such a consistency that it will solidify upon cooling. The boiling process is usually carried out in the field, wooden paddles being used for occasional stirring. The crude drug, Cape aloe, resulting from this inspissation is a hard tar-colored mass possessing a glass-like fracture. Within this material is to be found the active medicinal principle, aloin.

Current Crude Drug Production. Crude Cape aloe, often solidified in five-gallon gasoline tins, is sold to local dealers who in turn market it through export brokers located chiefly in Capetown, Mossel Bay or Port Elizabeth. Undoubtedly there is some internal consumption of this product in the Union of South Africa, but most of the Cape aloe produced is exported. During the five-year pre-war period of 1935–1939 the quantity exported totalled 4,690,996 pounds, representing an annual average of 938,199 pounds with an annual value of £16,855 (South African). Of this yearly total about a third was imported by Germany, a country whose pharmacopoeias, along with those of Switzerland and Austria, accept Cape aloe as the only officinal drug aloe. During the war years, 1944 and 1945, the annual exportation of Cape aloe decreased to about a third of the pre-war output. At that time the United Kingdom took roughly 40% of the production, followed by the United States (20%), Australia (12%), Southern Rhodesia (2%), and Canada and Switzerland (1% each). Since the war it appears that Cape aloe production is slowly rising again and may soon approach the pre-war figures. The principal sources of the drug aloe used in the United States are indicated by the following figures. During the calendar period 1938–1940 the United States imported a total of 748,267 pounds of drug aloe, of which 77,609 pounds (roughly 10%) originated in Africa and probably represent Cape Aloe (*A. ferox*). The remaining poundage represented West Indian Aloe (*A. barbadensis*) obtained chiefly from the Dutch islands of Aruba and Bonaire.

Primitiveness of Cape Aloe Industry. As shown above, the traditional techniques used in the collection of Cape aloes have remained unchanged through the centuries, and methods employed today are just as primitive as in the days of Thunberg and Sparrman. The collection of aloetic juice and its subsequent solidification through boiling and cooling

[9] The same method of collecting juice has been described by Balfour for the island of Socotra (Balfour, I. B., "Botany of Socotra", Trans. Royal Soc. Edinb. 21: 38, 1888, but because of the lack of prickles on the surfaces of the leaves of *Aloe perryi*, only two or three layers of leaves can be stacked at one time. Juice of the Socotran species is not boiled down but is thickened by simple air evaporation during a period of two months.

FIG. 17 (*Upper*). The new aloin plant at Aruba, N. W. I.

FIG. 18 (*Lower*). Interior of new aloin plant at Aruba, showing some of the machinery used in manufacturing U.S.P. aloin direct from the fresh juice of *Aloe barbadensis*. (*Aruba Esso News Photos*).

is perhaps the oldest agricultural extractive occupation of the Cape Province. Yet even today it can be called scarcely more than an unorganized peasant industry. In the early days the work of juice collection was done by "slaves or Hottentots" belonging to a few of the colonists on the aloe coast. Today, too, their modern descendants, the so-called "Cape coloured folk", continue to handle the harvesting of aloe leaves and, as has been noted above, in the same districts.

Unlike the West Indian aloe industry, where, as indicated above, an introduced species of aloe is cultivated, that of South Africa is based entirely upon the utilization of native plants growing in their natural wild condition. There are no cultivated stands or plantations. Indeed the number of available wild plants greatly exceeds the demand for their leaves. Occupying, as they do, submarginal land, unfit for any other agricultural pursuit, plants of *A. ferox* have continued to flourish in their native haunts. Their ability to persist in the area of their principal exploitation is due to the fact that the Cape aloe "industry" is not a destructive one. Since only the older lower leaves of any one plant are removed at the time of harvesting, the younger leaves and growing tips are thus spared to slowly replace those removed for their juice.

It is probable that the quantity of drug aloe produced in South Africa has remained more or less the same down through the years. Practically the whole South African production originates in the Swellendam–Mossel Bay sector, which represents only the westernmost part of the range of *A. ferox*. Variations in the annual production are attributable, among other things, to erratic yields caused by unpredictable weather. Severe drought, although not harming the plants, is said to stop the flow of juice and so may bring the drug aloe production to a virtual standstill. The result of such a drought was seen in 1949 when demand for the extract far exceeded the supply (11). Actually it is the opinion of the aloe cutters that the yield of juice per plant has been progressively diminishing over a long period (11), and if this is true it may be tied in with progressive encroachment of more arid conditions over many parts of the Union.

The smallness and unorganized nature of the Cape aloe "industry", the uncertainty of the kind and amount of competition from other aloe-producing areas, and the unprofitable prices obtaining for crude extract, all combine to relegate the harvesting and preparation of Cape aloe to persons at the bottom of the economic scale. Currently a peasant producer is paid a mere sixpence (approximately eight cents US) per pound of the crude extract (11). Apparently there has been little change since the eighteenth century, for Sparrman had this to say about this subject: "When . . . those who at present make it their business to buy up this drug at the Cape, do not give more than two or three stivers a pound for it: . . . it will not appear remarkable, that the Cape farmers do not think it worth their while to prepare this gum, unless they employ young children or other people, that can do nothing about it".

Future Outlook for Cape Aloe Industry. As long as such conditions prevail, little can be accomplished that might bring about a proper development of the industry, including such activities as selection of higher yielding strains of *A. ferox* and extension of its commercial exploitation throughout the natural range of the species. Despite the scarcity of spines on plants in the eastern part of its range, the juice could still be drained satisfactorily by abandoning the traditional conical stacking, which is dependent on the presence of surface spininess, and by using other methods of draining and collecting the juice. As

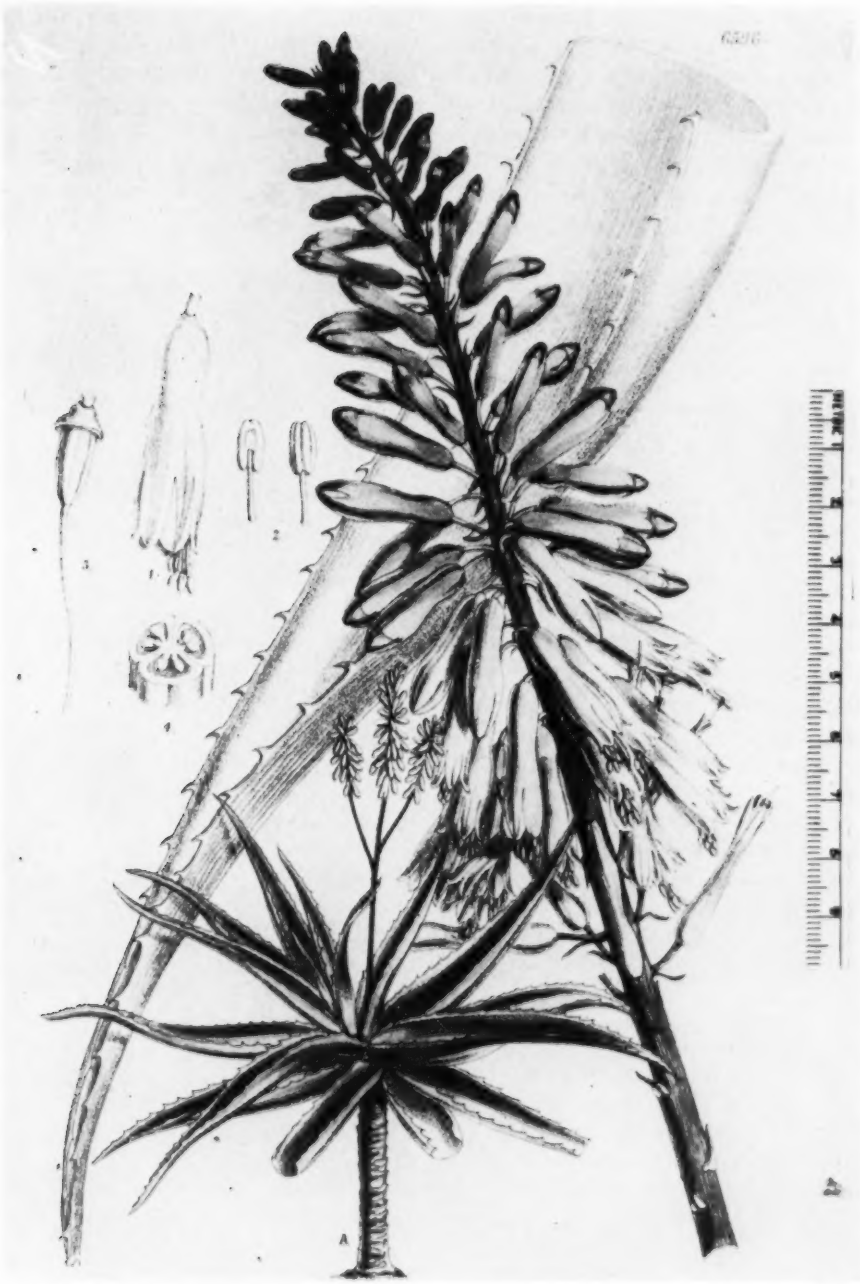

FIG. 19. *Aloe perryi* Baker, from a plate in Curtis's Botanical Magazine, 1881.

stated earlier, too, southern Africa is a land of aloes and there are other species just as abundant as *A. ferox*. A systematic chemical survey might show certain of these to be not only higher yielders of bitter aloetic juice but also sources of a superior drug product. If South Africa were to follow the example of Aruba by manufacturing U.S.P. aloin directly from the fresh juice of aloes, there might be a possibility of growth in this industry.

FIG. 20. *Aloe succotrina* Lam., growing on the Karbonkelberg, Cape Peninsula. Table Mountain in background. (*Courtesy R. H. Compton*).

Other Cape Aloes Credited as Drug Species. As mentioned above, *A. ferox* is, and has been in the past, the primary source of medicinal aloe in the Cape Province. This fact is substantiated by Reynolds (10) as well as by observations made by the present writer in the field in 1951. Nevertheless there have been numerous references, some of them recent, to other species supposed to be sources of Cape aloe. A brief discussion of each of these South African species, together with the references in question (in parentheses) here, follows:

Aloe africana Miller:—An arborescent species of the eastern Cape Province which has been confused (5, 15, 17) with *A. ferox*, probably because of its similar growth-habit, the partial coincidence of its range and the fact that it is a close ally (both species pertain to the subgeneric section, Pachydendron). *Aloe africana* does not occur in the drug-producing districts, but even if it did the species would probably be unacceptable to Cape aloe gatherers because the leaf surfaces are mostly glabrous without

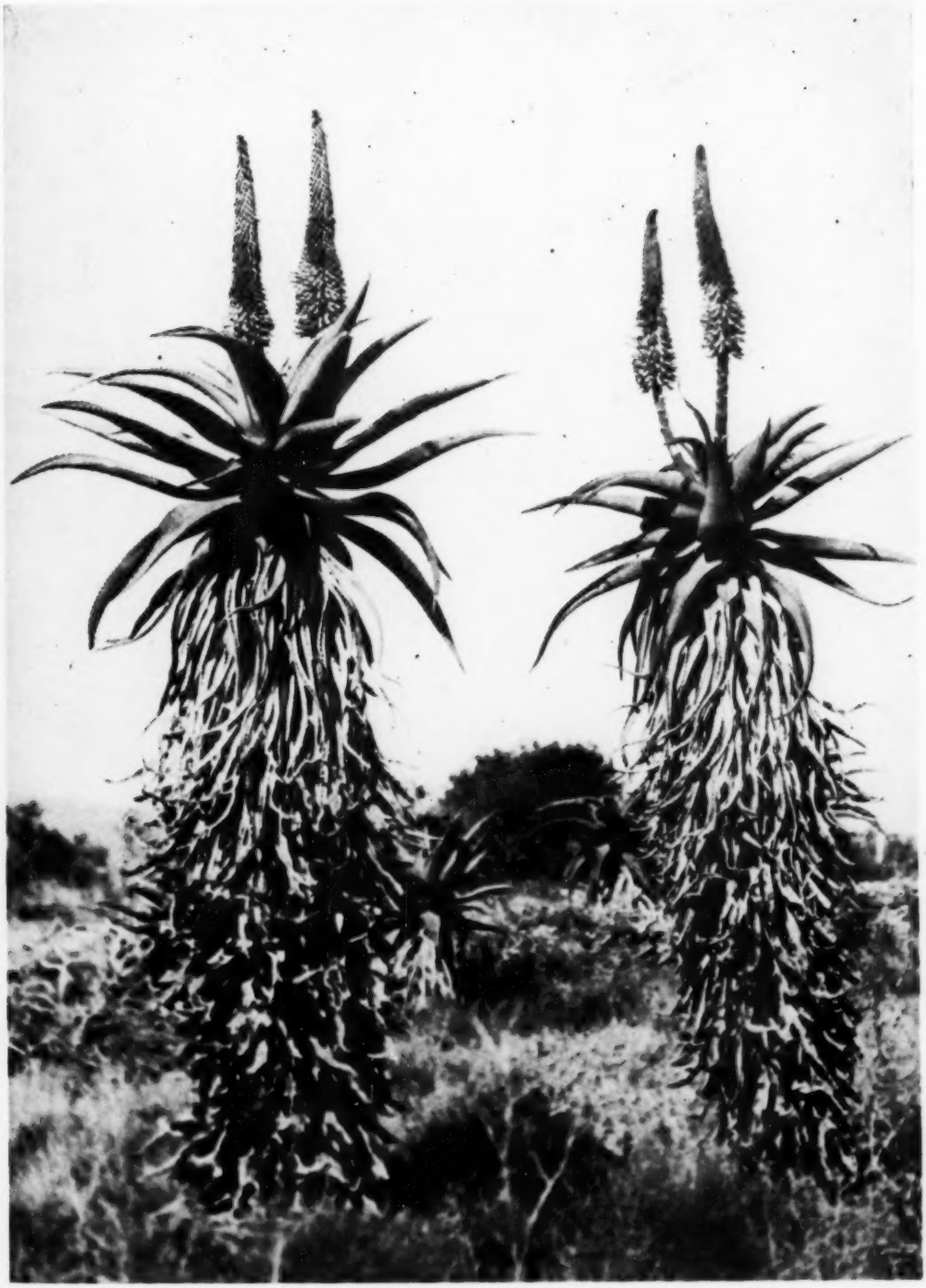

FIG. 21. A spurious Cape drug aloe, *Aloe africana* Miller, near Carlisle Bridge, Bedford Division, Cape Province. Height, eight feet. (*Courtesy Dr. G. W. Reynolds, Johannesburg*).

the abundant and "necessary" spines. "Large quantities" of drug Aloe, reputedly obtained from this species, are said to have been exported annually from the "Eastern Districts" in the middle of 19th Century (Pappe, C. W. L.: Florae Capensis Medicae Prodromus, 1850). The product obtained was reported by Pappe as "almost equally good, but not so bitter, nor so powerful as a drastic".

Aloe arborescens Miller:—This species is the most widespread of all aloes in southern Africa, ranging from near Capetown and following the mountain ranges north to Nyasaland. Commonly and widely cultivated as an ornamental, the species has been cited erroneously (15, 17) as one of the plants grown in the West Indies as a source of drug aloe. As indicated earlier, the species involved in the Caribbean is *A. barbadensis*. Reynolds states that the Mossel Bay aloe producers know this plant very well but affirm that the species is "never used" as a local source of Cape aloes. However, *Aloe arborescens* has a number of other local uses in the Union: the Zulus administer a decoction of the leaf to women just before parturition, and a cold infusion serves as a drench in the treatment of sick calves (17). Recently, and as a South African substitute for *A. barbadensis*, whose leaves are used similarly, the fresh juicy pulp of the leaves of *A. arborescens* has proven valuable in the treatment of X-ray burns (10).

Aloe candelabrum Berger:—Reynolds states that this species is a very close relative of *A. ferox*, belonging to the same section, Pachydendron. *Aloe candelabrum* is of restricted occurrence in several valleys of Natal. Although no reference has been made to this plant as a source of Cape aloes, it has been stated by Marloth (9) to be the probable source of a sample of drug aloe, collected in the past century and cited in the literature as "Natal aloe" (15, 17). There is no evidence that Natal aloe has ever been produced on a commercial basis.

Aloe marlothii Berger:—Another arborescent aloe with the vegetative habit of *A. ferox* and associated with that species in the section Pachydendron. *Aloe marlothii* grows in the hilly areas of eastern Bechuanaland, the Transvaal, Swaziland and Zululand (a part of Natal). It is as characteristic and dominating a feature in these areas as is *A. ferox* in the Cape Province. There is some difference of opinion as to whether this species or the preceding one was the original source of the South African drug aloe which became known as "Natal aloe" (10, 17). Marloth at first considered *A. marlothii* to be the source (8) but later favoured *A. candelabrum* (9). Neither has ever been a commercial source of drug aloe.

Aloe mitriformis Miller:—A plant limited to the "mountainous winter rainfall area" of the western Cape Province. The binomial here given does not appear in the literature of the drug aloes. However, there is mention (15) of *A. commelini* Willd. (as well as *A. multiformis*, apparently a typographical error for *A. mitriformis*), a species which Reynolds (10) treats as synonymous with *A. mitriformis*. There is no evidence that the latter species has ever been used as a source of Cape aloe.

Aloe plicatilis (Linnaeus) Miller:—This rather uncommon species has a local distribution from the Franch Hoek Mountains, east of Capetown, north to the Elandskloof Mountains. Because of the unusual distichous arrangement of its leaves, the plant has been of interest in horticulture under the name of Fan Aloe. Apparently the Fan Aloe was utilized very locally a century ago by South African colonists living within the range of the species. Its extract was described by Pappe (*op. cit.*) as a much milder purgative than that of *Aloe ferox* and resembling more the extract of *A. barbadensis*. Nevertheless, *A. plicatilis* has never been a commercial source of Cape Aloe.

Aloe spicata Linnaeus f.:—Although

FIG. 22. A spurious Cape drug aloe, *Aloe speciosa* Baker, at Koonap, between Fort Beaufort and Fort Brown, Cape Province. Height, eight feet. (*Courtesy Dr. G. W. Reynolds, Johannesburg*).

FIG. 23. *Aloe candelabrum* Berger in the Umkomaas Valley between Richmond and Ixopo, Natal. Height, ten feet. (*Courtesy Dr. G. W. Reynolds, Johannesburg*).

listed (15, 16) as a possible source of Cape aloe, the exact identity of this species is doubtful, as has been shown by Reynolds (10). The original description was rather incomplete and later ones are based apparently on mixed herbarium material, the vegetative part of which may represent *A. speciosa* Baker, a species resembling *A. ferox* in growth form. Certainly the range of *Aloe speciosa* coincides to a large degree with that of *A. ferox*, with which it hybridizes, and for this reason it is likely that *A. speciosa* is the species referred to in the citations. However, it is clear that, insofar as a drug aloe source is concerned, *A. speciosa* has merely been confused with *A. ferox*, the drug-producing species, because of their social habits.

Aloe succotrina Lamarck (inclusive of *Aloe purpurascens* Haworth, a synonym):—Although native to the mountainous country around Capetown, this species apparently has not been listed as a source of Cape aloe. However, it was long considered, though falsely, to be the source of Socotrine aloe[10], and occasional references (*e.g.*, 15) appear incorrectly citing *A. succotrina* as the plant grown in the Caribbean region and supplying West Indian Aloe. Like *A. arborescens*, *A. succotrina* is of horticultural interest, and it is possible that the latter species occurs in the West Indies as an ornamental; however, there is no evidence that it has ever been utilized as a source of bitter aloe.

The West Indian Aloe Industry

The Early Industry. There is little published information on the culture of aloes in the West Indies, save for Freeman's account of the now long-defunct Bardabos industry (4), a brief digest of which here follows together with notes on the recently rejuvenated aloe industry of Aruba. For certain information on Aruba, including illustrations of aloes on that island, the writer is indebted to Mr. C. H. G. Eman of the Aruba Aloe Products Company.

[10] For a discussion of this see (10).

FIG. 24. *Aloe marlothii* Berger near Waterval Onder, eastern Transvaal. Height, nine feet. (*Courtesy Dr. G. W. Reynolds, Johannesburg*).

FIG. 25 (*Upper*). *Aloe mitriformis* Miller at Van Puttensvlei near Lamberts Bay, Clanwilliam Division, Cape Province. This species, under the name *A. commelini*, has been listed incorrectly as a source of the drug, Cape aloe. (*Courtesy Dr. G. W. Reynolds, Johannesburg*).

FIG. 26 (*Lower*). *Aloe arborescens* Miller on Signal Hill near Umtata, Transkei. Height, nine feet. This species has been cited erroneously as a source of drug aloe in the West Indies. (*Courtesy Dr. G. W. Reynolds, Johannesburg*).

FIG. 27. *Aloe plicatilis* (L.) Miller on mountain slopes above the French Hoek Forest Reserve, Cape Province. Height, eight feet. The leaves of this species were apparently used locally as a drug source by South African colonists in the middle of the last century. (*Courtesy Dr. G. W. Reynolds, Johannesburg*).

During the heyday of aloe culture on Barbados, where waste rocky land on the Windward coast was utilized, plants of *A. barbadensis* were propagated by offsets obtained from mature plants after harvesting. The sets were planted in moist (not wet) soil in long beds, about 18 feet wide, in which the soil had been thoroughly prepared by forking and by application of barnyard manure. Trenches between the beds supplied ample drainage. Transplants, spaced about a foot apart, were lined up in rows approximately two feet apart. With reasonable care these plants produced a crop in a year, the leaves being cut after the inflorescence appeared (generally in the early months of the year) and had dried. As in South Africa, only mature leaves were cut, and these were stacked in v-shaped wooden troughs from which the juice drained into receptacles. The process of inspissation used in Barbados was also essentially the same. One-year-old plants produced on an average 100 pounds of drug aloe per acre; they reached maximum production varying from 500 to 1,000 pounds per acre the fourth year, after which time production declined and replanting was usually resorted to, though leaves were sometimes harvested from a planting for as long as a decade.

Contemporary aloe cultivation in the Netherlands West Indies is essentially the same as that described for Barbados. Aloes are said to have been introduced into Aruba from Africa in 1836. Until about 25 years ago, the cultivation and processing of aloes was the primary livelihood of the people of Aruba and Bonaire, successors to Barbados as the chief source of West Indian Aloe. In more recent years, because of the absorption of the labor supply by new oil refineries, the aloe industry on the Dutch islands had come virtually to a standstill. This probably accounted for recent but incipient aloe production in such areas as the Venezuelan coast and the Dominican Republic.

Modern Extraction Technique. A rebirth of interest in drug aloes in Aruba came in 1946 when a native of that island conceived the idea of producing U.S.P. aloin direct from the fresh juice of the plant, thus creating a lucrative industry from what had been formerly a rather unprofitable export of crude aloe. A factory was constructed and started operating in 1949 with an annual capacity of 90,000 pounds of aloin, which is the approximate annual consumption in the United States.

Prior to the construction of this factory, all Aruban aloe juice was boiled down in copper kettles over wood fires to a tarry mass containing about 10% of moisture. Nowadays the bulk of the fresh juice is collected in drums (harvesting takes place from April to November, the dry season) and is delivered to the plant where aloin is first extracted directly by a special precipitation method and is then purified to U.S.P. standards by crystallization. The total production is sold in the United States. The innate efficiency of such an enterprise, whereby the fresh juice is processed at the point of origin, assures the Dutch isles of the leading position in the production of drug aloes and aloin. This will undoubtedly result in economic repercussions elsewhere in the World wherever drug aloes grow.

Literature Cited

1. Adamson, R. S. The vegetation of South Africa. 235 pp. 1938.
2. Anonymous. The source of Barbados aloes. West Indian Bull. 3: 293–294. 1902.
3. Chevalier, Aug. Les Iles du Cap Vert. Rev. Bot. Appl. & d'Agr. Trop. 15: 733–1090. 1935.
4. Freeman, W. G. The aloe industry of Barbados. West Indian Bull. 3: 178–188. 1902.
5. Githens, T. S. Drug plants of Africa. African Handbook 8, Univ. Pa. Press. 1949.

6. Gordon-Brown, A. [Editor]. The yearbook and guide to Southern Africa. 1950.
7. Hill, A. F. Recent changes in the names of economic plants. Harvard Univ., Bot. Mus. Lfts. **10**: 143. 1942.
8. Marloth, R. The chemistry of South African plants and plant products. Presidential address to the Cape Chemical Society. 1913.
9. ———. Die Stammpflanze der Natal-aloe. Pharm. Act. Helvet. **3**(1): 10–11. 1928.
10. Reynolds, G. W. The aloes of South Africa. 520 pp. 1950.
11. Schauder, R. Unsatisfied demand for aloe juice. Farmer's Weekly Nov. 23, 1949.
12. Sims, J. *Aloe ferox*. Great Hedge-hog Aloe. Curtis's Bot. Mag. **45**: plate 1975. 1818.
13. Sparrman, A. A voyage to the Cape of Good Hope . . . chiefly into the country of the Hottentots and Caffres from the year 1772 to 1776. English trans., 2 vols., 2 ed. 1786.
14. Thunberg, K. P. Travels in Europe, Africa and Asia. 4 vols. English trans. 1794–1795.
15. U. S. Dispensatory, 22nd Ed. 1937.
16. Watt, G. Dictionary of the economic plants of India. 6 vols. 1899.
17. Watt, J. M., and Breyer-Brandwijk, M. G. The medicinal and poisonous plants of South Africa. 1932.

Utilization Abstract

Food and Chemicals from Unicellular Algae. The prospects of supplementing the customary sources of food for human consumption by cultivating unicellular algae and extracting fats and proteins from them have been under laboratory investigation for some years, principally at the Carnegie Institution of Washington, Division of Plant Biology, Stanford University; at the University of Texas; and at University College, London. Unicellular fresh water green algae of the genus *Chlorella* have so far been examined in greatest detail, but species of *Scenedesmus* have also received some attention. "The ultimate usefulness of mass cultured *Chlorella* or similar algae will probably depend upon its value directly or after simple treatment as a raw material for chemical industry or as a source of food. Until large scale production has been carried out it will be impossible to say with certainty whether the process will be economically feasible".

"Although it is known that fats containing the unsaturated acids found in *Chlorella* are acceptable as human food, it is not known whether intact *Chlorella* cells would be suitable for either human or animal food. Furthermore, the extraction of fat from *Chlorella* is by no means a straightforward process. In addition to fat, the lipid fraction contains a considerable amount of unsaponifiable matter which, although not yet analyzed in detail, is believed to have a high sterol content. *Chlorella* species contain appreciable quantities of carotenoid pigments which may act as vitamin A precursors; vitamin B is also known to be present in young cultures".

"As indicated earlier, investigations have so far been almost entirely confined to algae of the genus *Chlorella*. These, of course, only represent a minute fraction of the algal types which may prove to be of industrial or agricultural value. The Chlorophyceae, to which *Chlorella* belongs, includes a large number of forms, such as *Scenedesmus*, which may be of value. In other algal groups, such as the Bacillariophyceae and the Xanthophyceae, the reserve products are known to be rich in lipid. The former group (the diatoms) have already received some attention. A further group, that of the blue-green algae or Myxophyceae, may be of value, although little is known about them, and even less is known about the Chrysophyceae, Dinophyceae, Cryptophyceae and Eugleniaceae".

"It is obviously premature even to hazard a guess as to whether or not this type of industrial photosynthesis will ultimately produce new and cheaper food and chemicals. Preliminary findings look promising and it is not unreasonable to expect that the investigations now being carried out in this country [England] and in the U.S.A., Sweden and Israel will ultimately result in controlled utilization of solar energy with material benefit to man". (F. N. Woodward, *Ind. Chem. 28(331): 341. 1952*).

The Mango—*Its Botany, Cultivation, Uses and Future Improvement, Especially as Observed in India*

This delicious tropical fruit has been under cultivation for about 4,000 years and today it is grown on about two million acres in India, its original home. Nearly 1,000 cultivated varieties are known throughout the tropics of the world. The fruits are rich in vitamins A and C, and have better food value than apple.

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Early History

The mango, one of the most important and delicious of tropical fruits, has a long history in India, as evidenced by reference to it in early Sanskrit literature and by its prominence in Hindu mythology and religious observances. De Candolle (18) considered it as having been cultivated by man for over 4,000 years, and a mango tree is depicted in the sculptures on the stupa of Bharhut which dates from about 100 B.C. (10). In the travels of the Buddhist pilgrims Fahhian and Sung-Yun at an unknown date, a mango grove is mentioned as having been presented by Amrdarika to Buddha in order that he might use it as a place of repose. This important fruit was always mentioned in the notes of the early foreign travellers to India, *e.g.*, Hwen T'sang (632–645), Ebn Hankal (902–968), Ebn Batuta (1325–1349) and Lurdovici de Varthema (1503–1508). It appears from the available records that

Hwen T'sang was the first person to bring mango to the notice of people outside India.

The mango had an important place in horticulture during the rule of Mohammedan emperors in India. They promoted the practise of planting the best varieties available in big orchards. Akbar, the Moghul emperor who reigned in India from 1556 to 1605, planted near Darbhanga the Lakh Bagh, an orchard of 100,000 mango trees. Nothing perhaps more eloquently attests the importance of this fruit and the esteem in which it has long been held than this immense planting made at a time when large orchards of fruit trees were almost unknown. Relics of such orchards are still found in different parts of India. Most of the improved cultivated varieties of India today had their origin in those early days, since when they have been maintained under cultivation for over 400 years by vegetative propagation. The Ain-i-Akbari, an encyclopaedic work written during the reign of Akbar (about 1590 A.D.), contains a lengthy account of mango, giving information about the quality of the fruit and varietal characteristics. It appears from this account that a fairly good knowledge about mango culture and the characters of different varieties was gathered by the people of India during the sixteenth century or even earlier.

Origin and Distribution

Concerning the origin of mango, De Candolle wrote: "It is impossible to doubt that it is a native of South Asia or of the Malay Archipelago, when we see the multitude of varieties cultivated in those countries, the number of ancient names, in particular a Sanskrit name, its abundance in the gardens of Bengal, of Deccan peninsula, and of Ceylon even in Rheede's time (1683)".

The true mango is wild throughout the tropical forests of India, especially in the hilly tracts of North East India. Miquel (34) did not mention it as wild in any islands of the Malay Archipelago. According to Rumphius (59), it was introduced into certain islands of the Asiatic Archipelago within the memory of men living at his time in the early eighteenth century. Foster did not mention it in his work on the fruits of the Pacific islands at the time of Cook's expedition.

De Candolle's arguments, the history of the genus, the phytogeographical distribution of allied species, the fossil records, the occurrence of numerous wild and cultivated varieties in India, and other evidence suggest that the mango most probably originated in the Indo-Burma region (41), whence it spread under cultivation over the Indian subcontinent in an early age. The improved varieties were subsequently introduced into other regions of the world.

The mango is now cultivated commercially in all countries of southeastern Asia, especially in India, and in the Philippines, tropical Australia, the lowlands of South-East Africa, in Hawaii, and in the lowlands of Central and South America. In the Mediterranean region it is being tried in Egypt and in Palestine (51). The history of its introduction to different countries is discussed below in brief.

The Malayan name of mango (mangga) attests its origin outside Malaya, being the same word as the Tamil (south Indian) mangas, and produces evidence for introduction of superior races from India (9) into Malaya. The size of the seeds is too great to allow carriage by birds or other animals, but the frequency of its cultivation in Malaya suggests dispersal by human agency. Its introduction into the islands of the Malay Archipelago and other East Asiatic countries was very likely brought about by Indians making voyages to those areas during the Buddhist period

(fourth and fifth centuries B.C.). Wester (77) suggested that the mango was introduced into the Philippines during the first half of the seventeenth century.

Dissemination of mango throughout the world started with the beginning of commerce between Asia and Europe, as is true of many other tropical fruits and of spices. The Portuguese were the first to come to India, and seized the opportunity of trading in spices and other vegetable products of the East. It is most likely that early in the sixteenth century they carried the mango, plant and seed, from Goa (India) to East Africa, thence to West Africa and adjacent island possessions, and subsequently to Brazil. Captain Cook found the fruit in great abundance at Rio de Janeiro in 1768.

The mango was first introduced to Barbados in the West Indies about 1742, the tree or its seeds having been brought from Rio de Janeiro. It has become naturalised and is now growing plentifully in every district of Jamaica, after being introduced in 1782 through seed found on a French ship captured by a British warship (20). Mexico acquired mangoes from two sources, some from the West Indies early in the nineteenth century and others from the Philippines brought by the Spanish galleons which traded between Manila and Acapulco. Higgins (23) states that it was probably introduced to Hawaii first from Mexico, but more recent introductions have been from India, the Philippines and Jamaica.

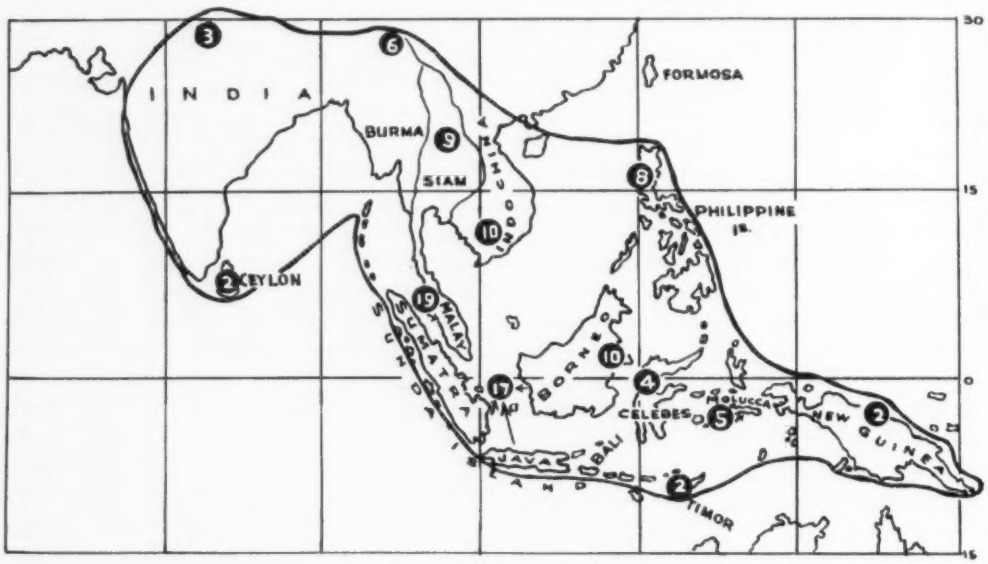

FIG. 1. Natural distribution of the genus *Mangifera*. The numbers within black disks indicate the numbers of species in the various countries.

In U.S.A. the earliest introduction appears to have been into Florida from Mexico in 1833. The second successful introduction was in the lower east coast of Florida in 1861–62. Grafted Indian varieties were first introduced in 1885, but the plants did not survive. The second introduction was made in 1888 through a shipment of 35 inarched trees from Calcutta. Since introduction of the trees into America, mango fruits have been gaining popularity and are

now sold in the markets of Florida and California.

Mango and Its Relatives

Since mangoes have long been cultivated by man and selections made for his needs, a great range of variation has been produced, as a result of which nearly 1,000 varieties have evolved. They are all included in the single species *Mangifera indica* L. (Anacardiaceae). The genus *Mangifera* consists of 41 valid species (36), distributed throughout Malaysia from India and Ceylon in the West to the Philippines and New Guinea in the East. Most of them are wild and economically unimportant, but some, listed in Table I, are cultivated for their edible fruits. They are classified into two groups and may be characterized as follows:

TABLE I

Species of *Mangifera*	Ceylon	India	Andamans	Burma	Siam	Indochina	Malay Peninsula	Sumatra	Java	Bali	Borneo	Moluccas	Celebes	New Guinea	Philippines
SECTION I.—DISC SWOLLEN															
Five *stamens fertile*															
1. *M. pentandra* Hook. f.	..	..	..	..	..	+	+								
2. *M. cochinchinensis* Engl	..	..	..	..	..	+									
One *stamen fertile*															
*3. *M. indica* Linn.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
4. *M. sylvatica* Roxb.		+	+	+	+	+									
5. *M. oblongifolia* Hook. f.	..	..	..	..	+	+	+								
6. *M. zeylanica* Hook. f.	+														
7. *M. altissima* Blanco.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	+
SECTION II.—DISC REDUCED OR ABSENT															
Five *stamens fertile*															
8. *M. lagenifera* Griff.	..	..	..	..	+	+	+								
One *stamen fertile*															
9. *M. macrocarpa* Bl.	..	..	..	..	..	+	+	..	+	..	+				
*10. *M. foetida* Lour.	..	..	..	+	+	+	+	+	+	..	+	+	+	..	+
*11. *M. odorata* Griff.	..	..	..	..	..	+	+	+	+	..	+	..	+		
12. *M. Kemanga* Bl.	..	..	..	..	..	..	+	+	+						
*13. *M. caesia* Jack.	..	..	..	..	..	..	+	+	+	+	+	..	..	..	+
*14. *M. caesia* Jack., var. *verticillata* (Rob.) Mukherji,	..	..	..	..	..	..	..	..	..	..	..	..	..	..	+
SPECIES DUBIA															
15. *M. Reba* Pierre.	..	..	..	..	..	+									

*Species widely cultivated.

Section I. Apart from *M. indica*, the common mango, the species of this section have smaller fruits than those of Section II, with very thin flesh. The wild races of *M. indica* also bear small

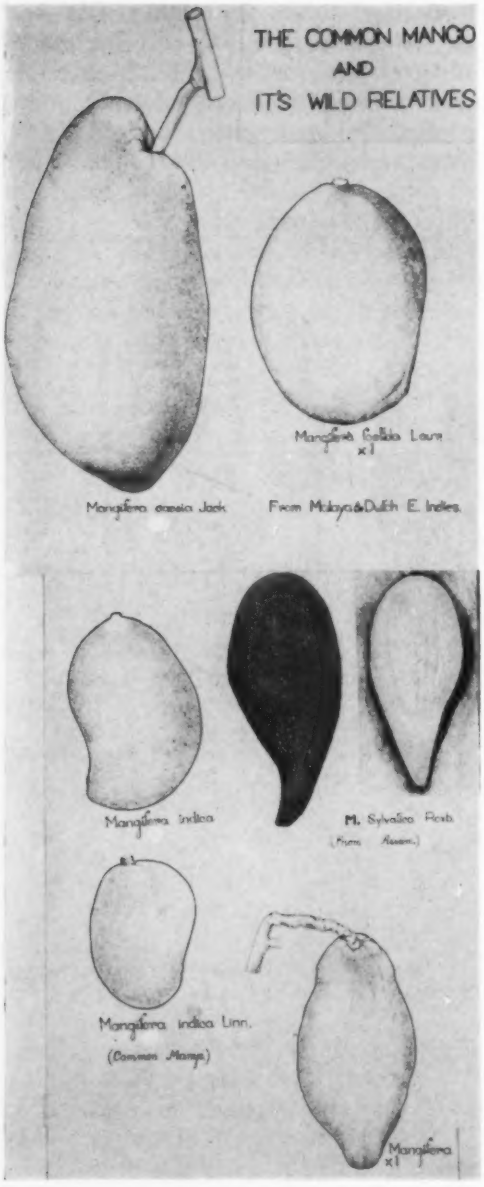

FIG. 2. Common mango and related edible species.

fruits with thin flesh. *M. pentandra* has spherical fruits of good flavour. *M. cochinchinensis* has fruits three cm. long liked by the people of Indochina, though of inferior quality. *M. sylvatica* has fruits six to eight cm. long with a thin slimy flesh having a fine aroma. It is almost free of fibres. *M. oblongifolia* has fruits four cm. long which are pickled unripe in Indochina or eaten after cooking. *M. zeylanica* has fruits six cm. long, almost of the same size and shape as those of *M. indica*. The flesh is thin, juicy and pleasantly acidic, possessing an agreeable flavour but traversed by innumerable soft short fibres. *M. altissima* has fruits five to eight cm. long with flesh almost free of fibres. These are used by the Philippinos for pickling.

Section II. *M. lagenifera* has fruits ten to twelve cm. long, with cream-coloured flesh two cm. thick traversed by innumerable fibres. Because of the fibre and foetid odour it is not much liked and little eaten. *M. macrocarpa* has obliquely oblong globose fruits, the size of a child's head, with yellow bitter-sweet flesh which is not relished. *M. foetida* has fruits eight to ten cm. long with flesh two cm. thick, traversed by many fibres. The fruits are much eaten by the Malayanese because the flesh is sweet when ripe, although the flavour is coarse with a disagreeable odour. *M. odorata* also has fruits ten cm. long with a distinctive flavour when ripe. The flesh is sweet but traversed by coarse fibres. Next to *M. indica* the fruits of this species are most liked by the people of Malay. Culture may make it a good fruit suitable for this region, where the grafted varieties of mango are not successful. *M. caesia* has fruits 18 to 19 cm. long with thick flesh traversed by coarse fibres. The flesh is juicy and acidic, but in one race it is sweeter than in others. Malayanese are fond of the fruit, but its odour is very objectionable. *M. verticillata*, a species reported from the Philippines and appearing to be a variety of *M. caesia*, is cultivated for its fruits which are superior to those of *M. caesia*. *M. Kemanga* has fruits somewhat similar to those of *M. caesia* and possessing juicy flesh. It is used in cur-

ries for its sour flavour. *M. Reba*, eaten by the people of Indochina, has fruits eight cm. long.

Extent of Cultivation in India

According to data collected by the Indian Council of Agricultural Research from the horticulturists of the Provinces, the total area under mangoes in India in 1945 was about 2,200,000 acres. The main areas were Uttar Pradesh, 1,322,656 acres; Madras, 250,900 acres; and Bihar, 217,517 acres.

Environmental Requirements

Climatic and other environmental influences considerably affect the development of the mango tree and the quality of its fruit. Each local environment has its own predominant type, more resistant to disease and more prolific under local conditions. Wherever the mango has been grown from seed for several generations, it seems to fall into environmental types. Within these local types arise a few oustanding specimens, preferred above the average and generally distinguished locally by name.

Climate. The best regions for commercial mango culture are those where a humid rainy season alternates with a period of well marked dryness during the flowering period of the plant. The trees readily grow in all tropical and sub-tropical climates with a mean shade temperature of 75° to 80° F., a normal minimum above freezing, and abundant soil or atmospheric moisture. They do best in areas commonly known as the "dry tropics", *i.e.*, within the belt of tropical influence, free from frost, where the seasons are fairly regular and well-defined. Such conditions prevail in the higher savannah regions throughout the tropical belt, from the plains to 3,000 feet elevation, between the tropical lowlands and the mountains (71).

In selecting new areas for extension of mango cultivation, one of the most essential considerations is absence of temperatures closely approaching that of frost. Tolerance of low temperature varies considerably among the varieties and has been studied in several Indian forms; seedling types were more resistant than grafted varieties (10).

With regard to the maximum temperature that mangoes can withstand, no exact data are available, but they grow well in areas registering as high as 118° F. or so.

Annual rainfall of 50 to 100 inches is suitable for mango, but it may be much less if irrigation is available. The total amount of rainfall is not so important as the season in which it occurs. Where the dry season coincides with flowering time, good crops of fruit are expected.

Soil. The mango is adaptable to a wider range of soils than many other fruit trees, provided the soil is sufficiently deep and well drained. The trees are often found on very light infertile sand which may be only a few feet in depth, and still produce flourishing growth if the subsoil is suitable (10). In Puerto Rico (28) they thrive best on a deep loose loam with good drainage and a high percentage of humus (28). Burns and Prayag (10) observe that the red soils of Dharwar in India, derived primarily from haematitic quartzite and containing very few pieces of rock, and the red laterite soils of Belgaum, Ratnagiri and Goa, are pre-eminently suited to mango. In India some of the best mango districts are situated on the great Indo-Gangetic Plain where the soil is deep rich alluvial loam, perhaps the best of all mango soils. An analysis of the surface soil from the mango orchards in the Saharanpur Botanic Garden shows that it contains:

Lime CaO	1.20%
Magnesia (MgO)	1.18%
Potash (K_2O)	2.73%
Phosphoric Acid (P_2O_5)	0.18%
Nitrogen	0.10%

Drainage is quite important. If the soil is permanently wet or poorly drained, the trees cannot be expected to fruit profusely.

Propagation

Mangoes can be propagated by two methods—as seedlings, or vegetatively through budding, grafting, layering or cuttings.

Seedlings. The mango trees which are now growing throughout the world are mostly seedlings (about 99% in India (69)), and the fruits produced by them are usually not of the same quality as the parents but are inferior, except in the polyembryonic varieties. The varieties producing superior delicious fruits are mostly of Indian origin and monoembryonic. Hence to maintain the quality of these good fruits, vegetative methods of propagation should always be adopted.

Though the general belief from casual observations is that monoembryonic seedlings do not produce fruits exactly like those of the parents, there are no accurate experimental data regarding this point. It is therefore desirable that further observations be made on the important varieties to determine the range of variation in their progenies. Cytological analysis of the Indian mangoes shows, however, that they are all allopolyploids and are therefore likely to display variation in their progenies (40).

Seedlings in India are said to be mostly monoembryonic, except about a dozen races found in South India (48). Those in the Philippines, Puerto Rico, Hawaii, Indochina and America are mostly polyembryonic (28, 55, 77). The latter types can be propagated by seed, as they generally produce fruit of the same quality as the parents.

The high percentage of seedlings among cultivated mangoes is a result of the ease with which they can be raised and the low cost of their production in comparison with that of grafted types.

Vegetative Methods. Vegetative propagation should be limited to those varieties which are abundant and regular bearers, of desirable habit and growth, resistant to anthracnose and other diseases, and frost-resistant (particularly for propagation in sub-tropical areas), and which fruit within four years after grafting. Many methods for such propagation have been recommended by horticulturists throughout the mango world. The most commonly used techniques are inarching, or grafting by approach, practised in India from very early days, and the more recent methods of budding, practised in Hawaii, Florida and other areas. All these methods may be briefly described as follows:

(a) Cuttings. Not successful as yet, but further trials should be given with root-promoting hormones (10, 48, 61).

(b) Layering. Also not successful (10).

(c) Gootee (Marcotte). A slow, cumbersome and uncertain process (10), not suitable for commercial practise. A gootee, as prepared in India, involves removing the bark in circular form from one to two inches along the scion stem and then covering the exposed stem with a mixture of mud and cow dung, tightly secured with some kind of moisture-retaining material. It takes several months for roots to strike, and the soil must be kept moist during this period. The procedure is troublesome, and success depends on the uncertain production of new roots. This technique is a modified form of air layering.

(d) Budding. Raising seedlings as stock plants is a prerequisite for bud grafting as well as for other grafting operations described later. Plump seeds from healthy, vigorous, regularly bearing trees of monoembryonic varieties should be collected and sown immediately after the fruits are mature, as they lose viability within a month or so. They should be dehusked, *i.e.*, removed from the hard endocarp covering, to ensure better and

rapid germination, and planted in soil, in coral sand on propagating benches in open sunlight, or in pots (48, 55).

There are various methods of budding, but none of them is satisfactory except in experienced hands. Particular skill is required to enable the propagator to recognize the proper type of budwood and to know when the stock plants are in the proper state of vegetative activity. The method was first tried for mango by Wester in the Philippines in 1904, and Mr. Orange Pound of Coconut Grove, Florida, achieved great success with it about the year 1910. Perhaps it has nowhere been successful as a commercial method for nurserymen except in Florida. Consequently it has not found favour in India, Palestine or in several other countries (48–51), although good success has been achieved in experimental work in horticultural research stations.

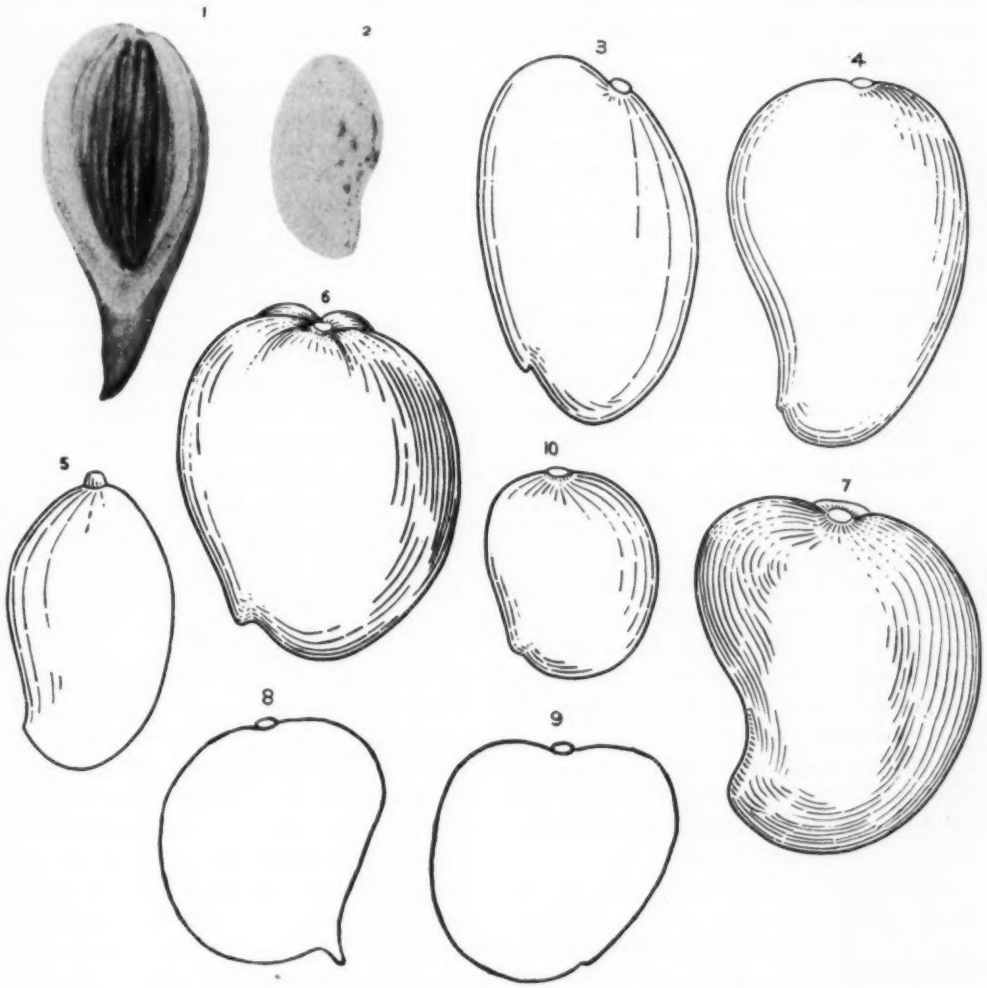

FIG. 3. Fruits of wild Indian mango: 1, *M. sylvatica;* 2–10, *M. indica;* 2, type from Burma border; 3–10, types from Orissa hills (Kalahandi).

The best season for budding is warm weather when the stock plant is in active

growth (May–June in Florida). When the seedlings have attained the diameter of a pencil, they can be budded, although they may be allowed to grow a little larger. The proper time for the operation is when the plants are coming into the flush, *i.e.*, giving out new leaves, as the bark can easily be separated from the wood at that stage.

(i) Shield-budding. This is the method usually practised in Florida (57). Budwood is taken from the ends of young branches, but not from the latest growth; the two preceding growths are better. One important factor is that the budwood and stock plant be closely similar as regards size and maturity of wood.

An incision is made in the stock plant in the form of a T or inverted T, a bud (preferably one and a half inches in length) inserted in it and wrapped with wax tape or other suitable material. If the bud is green after three to four weeks, indicating union with the stock, the top of the stock plant is cut back several inches to force the bud into growth. A few weeks later the top is cut back further and eventually trimmed off close above the bud when the latter has made growth of eight to ten inches. Higgins (24) also described a method of shield budding.

(ii) Flap budding. This differs from shield budding by insertion of the bud inside a flap and covering it completely with the flap (48).

(iii) Patch-budding. A patch is removed from the stock where the bud shield is tied in position, keeping only the bud exposed.

(iv) Budding in situ. Because of the difficulties of budding in pots and subsequent high mortality rate during transplanting in the field, Singh and Khan (69) made trials of budding in the fields where new orchards were to be established, and met with considerable success. An indication of this process was first given by Wester. It differs from the other methods by budding three-year-old stock plants, planted in orchard pattern in the field, so that the rate of mortality is less after transplanting. The method should be given further trial to determine how it fares under different conditions.

(e) Grafting. As already noted in the discussion of budding, raising of seedlings as stock plants is a requisite for grafting operations. Plump seeds from healthy, vigorous, regularly bearing trees of monoembryonic varieties should be collected and sown immediately after the fruits are mature, since they lose viability within a month or so. Their hard endocarp covering should be removed before planting.

(i) Rootstock for grafting. The root stock problem for mango has not yet been properly worked out. The meagre data that are available indicate that Philippine seedlings should not be recommended, as they have weak roots (71). Some wild types in the Pachmari hills of India are frost-resistant, a quality which they transmit to scions when used as stock plants (10). Although the general practise is to use healthy seeds from vigorous trees without regard for other qualities, Singh (70) recommends seeds of varieties with syrupy fruit pulp in preference to those with firm pulp.

There is a difference of opinion as to the age at which stock should be grafted. Kinman (28) and Pope (55) suggested that stock be six to eight months old and three-eighths of an inch in diameter, but Burns and Prayag (10) recommended one-and-a-half to two-and-a-half-year-old stock for grafting, and Naik (48) mentioned one to one and a half years as the usual age.

Experiments with other species of mango and even other genera also did not show encouraging results. Burns and Prayag (10) reported use of *Semecarpus Anacardium*, *Spondias mangifera*, *S. acuminata* and *Holigarna Grahamii*, but without success. Collins reported successful grafting of mango on cashew

(*Anacardium occidentale*) in Martinique, with the fruits so produced double in size and free from fibre, but he suggested seeking verification of this result. Observations in Ceylon indicate that *Mangifera zeylanica* is less promising as a root stock than was at first thought (53).

The above reports indicate that there is no conclusive evidence regarding the desirability of any particular type for use as stock. It is reasonable, however, to expect among seedling races important differences in vigour of growth and perhaps in their effect on productiveness and other characteristics of the scion. The subject has not yet been properly investigated and deserves additional attention.

(ii) Inarching or grafting by approach. This is the commonest system practised in India, for it is easy to operate. The potted stock plant is placed in such a position that a branch of the scion tree is easily brought into contact with it. A strip of bark two to three inches long with a thin layer of wood attached to it is removed from the stock plant, nine to twelve inches from the soil surface, and a similar strip removed from the scion shoot, which should be healthy, full of foliage and of the same thickness at the place marked for grafting as the seedling. The cut surfaces are closely fitted together and at once tied firmly with raffia, banana fibre or twine. It takes nearly two months to effect perfect union. A month and a half after grafting, a cut is made in the scion between the point of union and the parent tree, which is deepened after a week, and the scion completely severed after another fortnight. The original top of the stock is then removed. The cuts are later trimmed and tarred.

The best time for inarching in India is from July to February. A hot and dry period as well as heavy rain during inarching is not congenial for the operation. Although inarching is very tedious and involves several expensive operations—potting, erection of special scaffolding, daily hand watering—any other method of vegetative propagation is not likely to be acceptable to mango nurserymen in India unless success is assured. Until recently the high cost of mango trees was caused by this slow and laborious method of propagation which seriously handicapped extension of mango orchards by planting of grafted varieties outside India. Recent introduction of budding methods in America, Hawaii and elsewhere have corrected matters.

(iii) Tongue graft by approach. A modification of the preceding suggested by Burns and Prayag (10).

(iv) Saddle graft, (v) whip graft, (vi) wedge graft. These three methods, described by Burns and Prayag (10), are slight modifications of the third process. In whip and wedge grafts the scion is detached from the plant at the very beginning. These two should be given further trial to see how far they succeed.

(vii) Side-tongue grafting. Pope (55) recommended this method in Hawaii. Both stock and scion must be in an aseptic condition. The cut surfaces should be two to two and one half inches long and smoothed so that they fit perfectly when placed together.

(f) Top-working. Top-working involves either budding or grafting old or unfruitful trees after cutting away all or most of the branches, sometimes leaving only two or three feet of trunk (10, 28). Naik (48) recommended inserting three or four side graft scions on the tree trunk, keeping the top intact so that the crown of the tree will not be sacrificed if the grafts fail. When any of the scions successfully combine, the tree top is sawed down.

Extensive experimentation in top-working of mango trees is much to be desired, and greater resort to it will help considerably in the improvement of mango production, especially in India. Since the majority of mango trees are of

inferior quality because of seedling origin, this process will be very useful for improving the production of mangoes if a thorough drive is made in several countries of the world. In addition to improving the quality of fruit, the unproductive old orchards, common in India and elsewhere, could be renovated by it. I completely agree with Popenoe's statement to the effect that " Perhaps no other field in tropical agriculture offers such opportunities for immediate result as this ".

Establishment of New Orchards

The best sites for mango orchards are those which have good drainage and soil of such nature that it will not dry out thoroughly when no rain falls for a week. Burns and Prayag (10) suggested deep alluvial soil near rivers as ideal for new plantations, but the site must be above flood level, as young trees do not tolerate submerging for any length of time. Virgin soil of forests or grass lands and cultivated ground are suitable, provided they are over three feet deep and have a well-drained substratum.

Before planting, the land must be ploughed and levelled, and arrangements made for drainage. Planting should be 35 feet apart in squares with rows each way. In better soils the spacing may be 40 feet or slightly more. Holes, two to three feet broad and deep, should be prepared in advance of planting and manured with bonemeal, farmyard manure or wood ash in suitable doses six to eight months before planting before the monsoon. Where rainfall is less than 60 inches per annum, the planting should be done at the break of the rains; where it is over 60 inches, at the end of the rains.

Orchard Management Problems and Practices

During the first four or five years the trees should be encouraged to make vigorous growth. After that the aim should be to induce them to produce good crops of fruit. The object of early culture is therefore different from that of later years. The young growing tree can be given both water and fertilizer in liberal quantities; the mature tree, on the other hand, must be encouraged to flower and fruit by withholding water and fertilizer during certain periods of the year (57). The cultural requirements of mango are not yet thoroughly understood, but it is known that varieties differ greatly in their response to tillage, irrigation and manuring.

Irrigation. As a rule, a grafted mango tree requires irrigation for four years. Thereafter no water should be given unless the tree shows signs of withering (10). In well-established orchards the trees should be irrigated during flowering, once a fortnight till the fruits reach their full size, and then stopped to allow the fruits to ripen. Owing to insufficient annual rainfall in Palestine and other areas, regular irrigation during summer is necessary. Experiments in Palestine indicate that the mango can tolerate up to 200 p.p.m. of alkalinity (51).

Manuring. Burns and Prayag (10) recommended various doses of farmyard manure, bonemeal and ashes for mango trees of different ages, but Naik (48) states that " in regard to this matter, sufficient amount of reliable data is not available to advance definite recommendations ". In most orchards of India " manuring of bearing trees is almost an unknown practise ". During the first three or four years two to five baskets of well-rotted cattle manure or two pounds of groundnut cake, with or without two pounds of bonemeal, may be spread around each tree.

Sen and Roy (67) made preliminary observations on the mineral nutrition of one variety, Langra, in pot culture in quartz sand, giving 11 treatments consisting of varying concentrations of N, P and K. After a study of three years

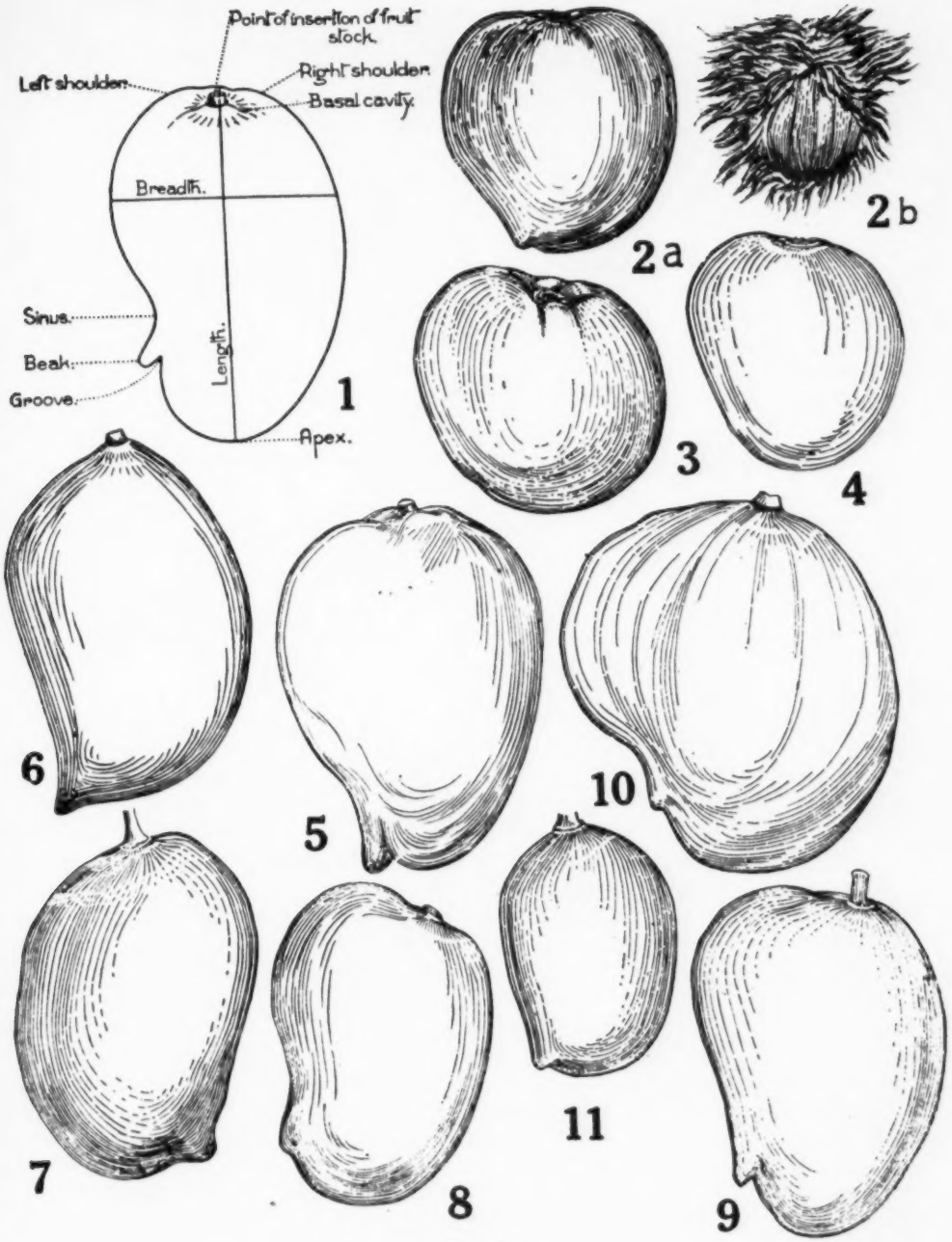

FIG. 4.

FIGS. 4–6. Fruits of cultivated Indian mangoes: 1, diagrammatic drawing of a fruit, showing descriptive characters. SPHERICAL VARIETIES: 2, Latra (creeping); 3, Sabsang; 4, Dudhoe. OVATE-OBLONG VARIETIES: 5, Nazuk Badan; 6, Kalapady; 7, Laskarshikhan *; 8, Shiredachan; 9, Biru Pasand; 10, Pathre; 11, Karrukkan; 12, Mohun Bhog *; 13, Bombai *; 14, Kohitur; 15, Kishenbhog *; 16, Shadwalla; 17, Fazli *; 18, Banganapalle; 19, Bhuto Bombai *; 20, Jagannath Bhog; 21, Kalapahar *; 22, Purushottam Bhog; 23, Bhowani Chowras; 24, Luzzat Bux; 25, Nasrat Pasand; 26, Gopal Bhog; 27, Langra *. LONG VARIETIES: 28, Anupam *; 29, Bangalora * or Totapuri *; 30, Shuroia; 31, Baramassia; 32, Jhumko Fazli; 33, Begum Pasand; 34, Dilpasand; 35, Khanum pasand; 36, Aman Daseri *.

* The asterisks indicate varieties of good quality.

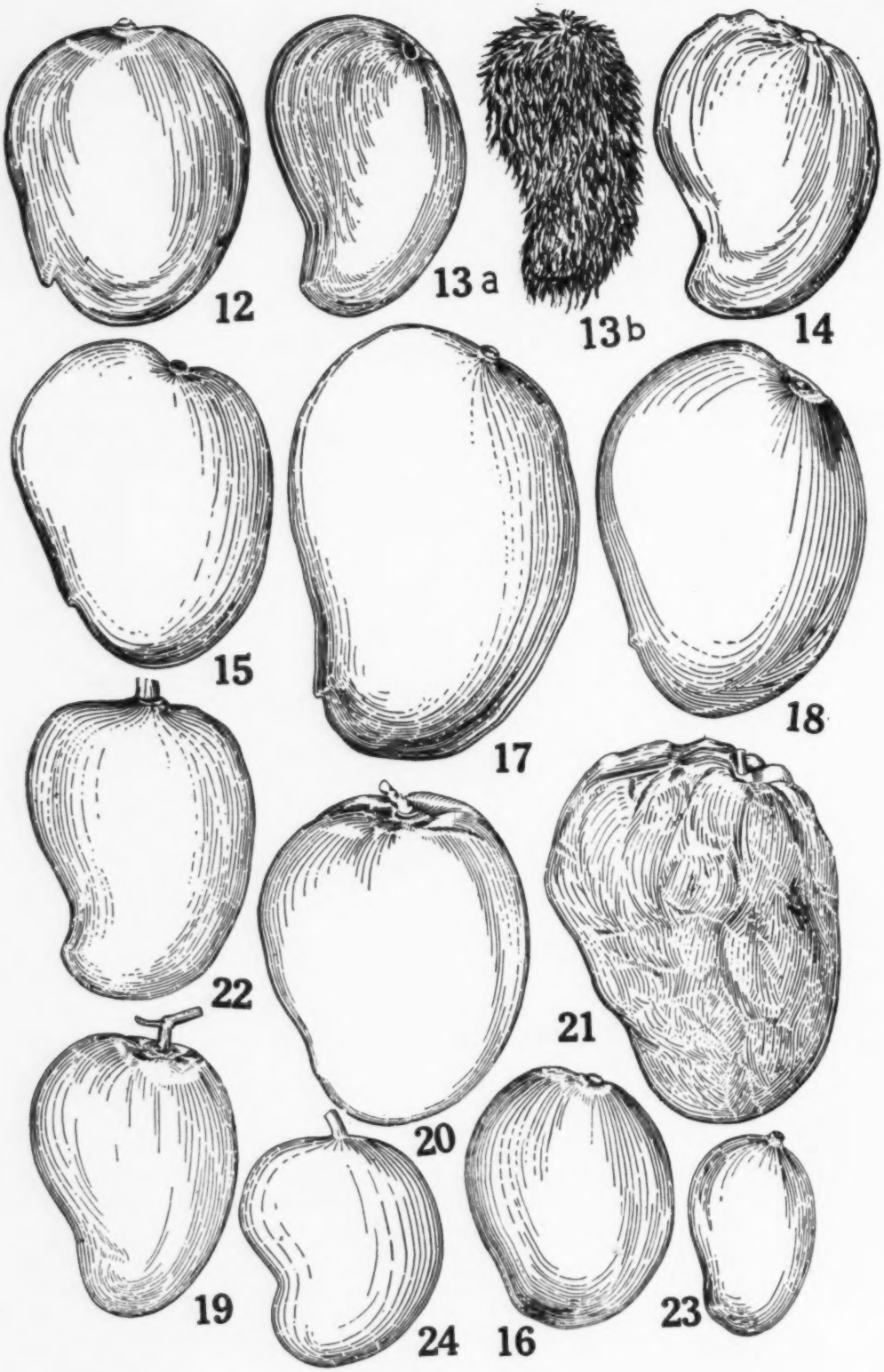

FIG. 5.

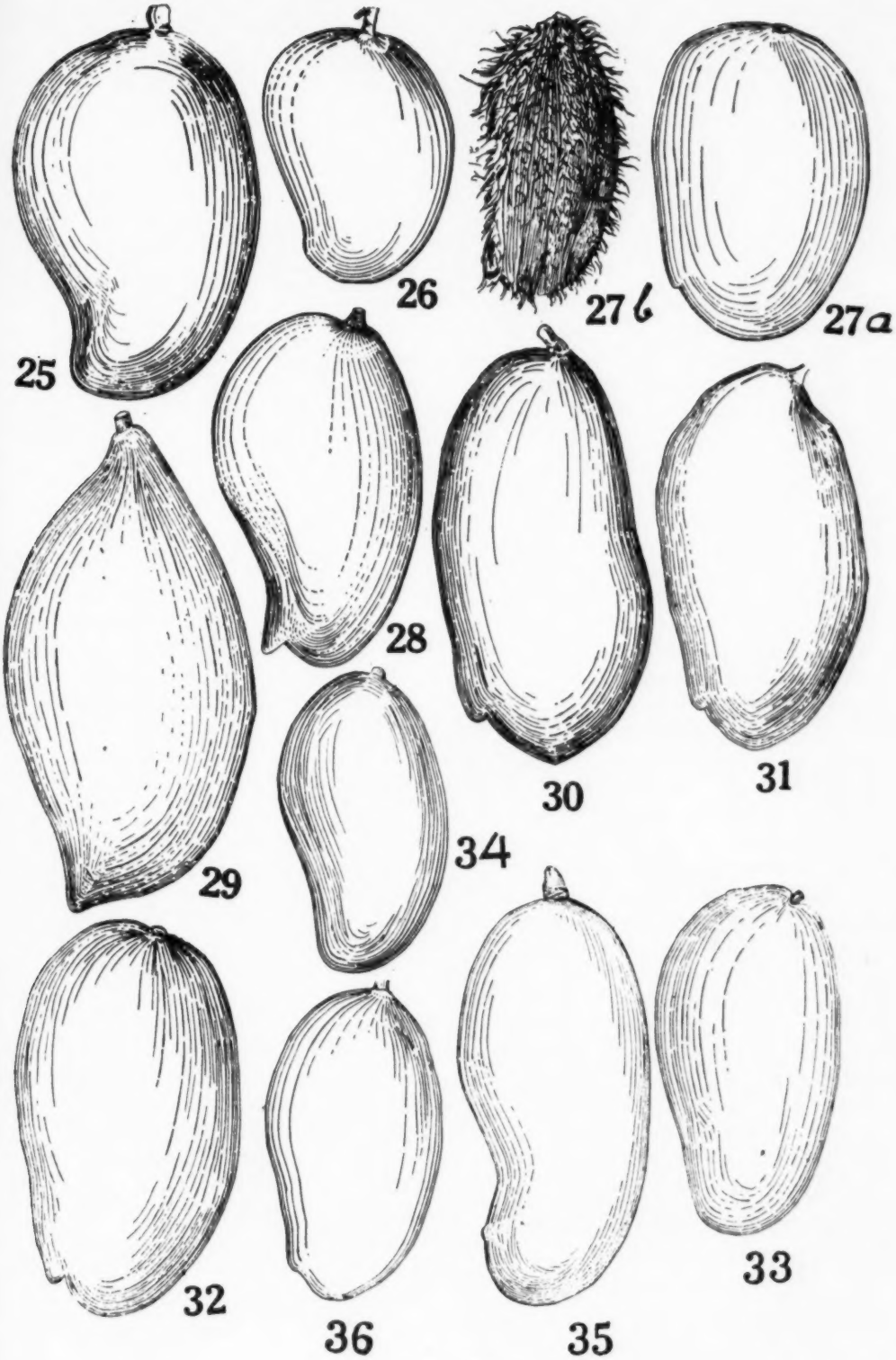

Fig. 6.

they concluded that the supply of nitrogen controls the uptake of other elements and determines growth. Mangos cannot withstand K deficiency to any degree, and the outstanding treatment of mango nutrition appears to involve maintaining a suitable balance between K and N.

Popenoe (57) refers to experiments in Cuba and Florida where liberal applications of potash encouraged larger crops than were obtained otherwise. A standard commercial fertilizer especially used in Florida contains: ammonia, 5–6%; phosphoric acid, 7–9%; potash, 9–11%. Similar investigations have been pursued in India at Sabour (Bihar), and recently Roy and co-workers published the results of their detailed investigation regarding the nutritional requirements of three important varieties, Langra, Bombai and Fazli.

Intercropping. During the early non-bearing stage, it is profitable to intercrop mango plantations with any kind of vegetable or leguminous crop, *e.g.*, sunnhemp, horsegram, cowpea (*Vigna catjang*) or *Dolichos biflorus*. Even small fruits like papaya and pineapple can be grown if kept away from the trees. When the trees attain the bearing stage, one or two ploughings or hand diggings of the soil every year is necessary to conserve moisture and keep off weeds. Occasionally, green manuring of the plantation with a leguminous crop and ploughing it during the monsoon are beneficial.

Pruning. According to Wester (77), it is not known whether pruning is necessary, but Burns and Prayag (10) recommend it early to give proper shape to the trees. Pruning of bearing trees has to be done judiciously to induce flowering immediately after the rains.

Floral Biology

Alternate Bearing and Fruit Bud Initiation. Although some grafts may begin to bear a few flowering shoots the second year after planting, most mango grafts do not flower until after the fourth year. The trees usually are irregular bearers, *i.e.*, they do not flower every year. This is a great handicap from the commercial point of view, as it leads to the production of huge quantities of fruits once in two, three or four years, and very few fruits the other years, *i.e.*, the "off" years. The price of mangos fluctuates according to the size of the crop, and orchardists generally do not get good returns for their crops during the "on" years, for the price then goes down. This problem has attracted the attention of various workers (47, 68), and several cultural methods have been recommended to induce the plants to flower regularly. Sen (63) worked very intensively on the problem at the Fruit Research Station, Sabour, India.

Fundamentally the phenomenon of flowering depends on the growth habit of the plant. A vegetative flush immediately follows the bloom. This is the first flush of new growths, and, as a rule, these growths are produced from terminal buds on the previous season's shoots that failed to blossom. A second flush of new growth arises as laterals on those shoots which produce panicles but fail to form fruit. A third flush of new growth arises after harvest, consisting of laterals on bearing shoots, terminals on weak growths of the previous season which fail to produce any growth, or secondaries on the current year's growths. Under North Indian conditions the mango blossoms from January to March, and the first flush appears from February to March, the second in April and May, the third from August to October. With the end of the rains and the beginning of winter the mango shows a brief check in growth in November and December which marks the end of the season. It has been determined that blossom bud differentiation begins in October or November (43, 65).

Under South Indian conditions, where

summers and winters are milder than in North India, the check in growth is not pronounced, and on the east coast of Madras, where there is a second monsoon during winter, it is hardly noticed. The times of flowering and vegetative flushes may vary somewhat in the different regions, or in the same region in different years according to climatic variations.

Among the shoots of the various flushes, those appearing early in the season (February to May) usually bloom the following season, as they complete growth during the summer rains, accumulate plenty of reserve sugars, starches and other carbohydrates, and attain physiological maturity by the time of blossom bud differentiation (61, 68). The shoots that appear late in the season fail to make sufficient growth for attaining maturity within the current season. They come to rest immature and grow again the following season, *i.e.*, produce vegetative growth of the first flush.

Initiation and development of new shoots depend primarily on the supply of nitrogen and moisture (63). The ideal condition for mango to produce shoots and develop them properly so as to attain maturity for blossoming the following year appears to be to have appropriate nitrogen supply and sufficient moisture during summer and early but not late rains. If there are heavy rains during blossom bud differentiation, even the shoots which may have attained maturity lose the capacity for blossom formation and produce only vegetative growth the next season.

A shoot that blossoms accumulates more reserve carbohydrates than one that does not blossom, resulting in a relatively high carbohydrate-nitrogen ratio or, in other words, a physiological depletion of nitrogen in its tissues. Heavy blossoming of a tree is accompanied by proportionately high nitrogen depletion. Whatever nitrogen is available contributes to reproductive growth, while vegetative growth is limited. The blossoms and fruits use up the accumulated reserves of the tree, exhausting it, and the greater the bloom and yield, the greater the exhaustion. Under such conditions the new growths after harvest cannot, as a rule, mature within the current year; they grow and mature the following year. Even if such a flush after harvest fails to appear, the tree makes abundant new growth the next year, and these growths acumulate abundant carbohydrates, thus once more pushing up the C/N ratio in the tree. This results in a heavy bloom but poor growth the following year. In this way the biennial or alternate bearing habit is established. As long as the weather and/or cultural conditions do not interfere, the alternate bearing rhythm continues and results in heavy blooms and crops of mango some years followed by one or two years failure before there is a heavy crop again.

Although nearly all the best Indian varieties regrettably are alternate in bearing, there are some types in which alternation is less pronounced. These display a larger number of " mixed panicles ", *i.e.*, inflorescences with leafy growths in between. The Fazli mango has such panicles and shows definitely less alternate bearing tendency (63).

Although alternate bearing is common in mango, Naik (48) has observed that trees of one variety in one garden may be low cropping or sterile while other trees of the same variety in a nearby garden may bear heavily. He regarded this difference as resulting from improper selection of scion parent and suggested that heavy yielding, regular-bearing and healthy parent trees always be used for scions.

Although blossoming of the mango depends to a great extent on C/N ratio, Sen (63) considers further elucidation of the factors governing fruit bud differentiation as essential. He suggested that the resultant effect may be one of a special hormone, and that a heteroauxin

may be discovered for practical use in inducing flowering.

Induction of Regular Bearing. One of the essential factors for flowering appears to be a check in growth at the proper time. It is possible that a high C/N ratio causes the cessation and thus favours flowering. Some cultural method for inducing such inhibition would therefore seem necessary if regular flowering is to be maintained. Several methods have been recommended.

In one, proposed by Sen (64), the important feature is not to allow the trees to suffer from nitrogen starvation, but at the same time excessive nitrogen must not be given. If in any year a tree fails to produce sufficient new shoots during summer, nitrogen should be applied to it in a quickly available form, *e.g.*, sulphate of ammonia at the rate of five pounds for six- to eight-year-old trees, to ten pounds for 15- to 20-year-old trees about the beginning of June, three to four weeks before the rains set in. Firminger (21) suggested exposing the roots for two or three weeks in November and covering them with fresh earth and manure in December. Kinman (28) tried girdling in Puerto Rico. Wester (77) reported a method of smudging, practised in the Philippines, which deserves attention. The trees are smoked day and night for one week in August from a specially prepared fireplace under each tree. Thereafter light fires are made morning and evening for a month or so till the trees bloom. He claims that mango can be forced to flower any time of year by this method. Later Alcala and San Pedro (1) and Lanuza (29) carried out other experiments on smudging in the Philippines, and asserted that the method is successful in enforcing flowering, but laborious and expensive. Further trials should be given to establish the economics of the process and to find out the essential factors for enforcing flowering.

Time and Duration of Flowering and Flowering Habits. The time and duration of flowering vary in different varieties. Climatic and soil conditions have marked effect on the time of flowering; in India it varies from November to March, the mangoes of South Madras flowering first, whereas those in Bihar and U.P., the main mango growing tract, blossom last. The time of flowering in America is also from January through March, in the Philippines in December and January (10). The local types in Java flower still earlier, from June to August, and bear fruits to maturity in October and November (7).

In addition to the variation in time of flowering in different areas, there is wide variation in different varieties growing under identical conditions in the same area. It appears, therefore, that initiation of blosoming in mango is a varietal character (49).

Though the majority of varieties blossom once a year, some varieties in India, *e.g.*, Neelum, Rumani, Allipasand, Bangalora and Baramasia, are double or triple croppers, *i.e.*, they flower over a long period in two or three flushes per year and are not restricted to any particular season (49, 63).

Floral Organogeny. The inflorescence of mango is a branched panicle with the flowers arranged at the ends of ultimate cymules. It arises from the tip of individual branches and bears numerous polygamous flowers, *i.e.*, male and bisexual. Differentiation of the flower bud, the growth and development of the floral organs, the male and female gametophyte, fertilization and the development of fruits have been studied (19, 25, 27, 31, 47). Development of the floral organs of both hermaphrodite and staminate flowers is acropetal. They arise as follows: sepals, petals, stamens and pistil. In the staminate flowers the pistil is abortive. Usually only one of the stamens becomes functional, but occa-

sionally two or three of them may elongate and develop a few pollen grains.

Period of Flowering. Some varieties develop all their flowers within ten days after the first bud opens, whereas others may take several weeks or even months (57). The latter types have a better chance of setting fruit because of the longer period available for pollination and for overcoming unfavourable weather conditions. The period between the opening of the first and the last flowers in different Java varieties is 11 to 29 days (7). It is interesting to note that all the wild forms of *M. sylvatica* and *M. indica* come to full bloom at the same time, and flowering is over in a fortnight.

Sex Distribution. The panicles of mango vary in length from a few inches to two feet. Each panicle carries from 200 to 4,000 flowers, even up to 9,000, and the number of panicles per tree varies from 600 to over 6,000 (7, 32, 57). Popenoe (57) observed that the percentage of perfect flowers varies from two to 70, according to variety. The total number and the percentage of perfect flowers in some Indian varieties, as determined by Sen (61), Naik and Rao (49) and the writer, are given in Table II.

TABLE II

Variety	Number of flowers per panicle	Percent bisexual flowers
1. Bombai	1,249	9.00
2. Langra	978	35.60
3. Fazli	2,996	15.50
4. Jehangir	1,961	1.25
5. Imampasand	5,827	9.12
6. Olour	2,024	4.68
7. Kishenbhog	2,750	5.00
8. Safdar pasand	3,000	20.00
9. Laskarshikhan	2,000	10.00
10. Kalapahar	1,750	20.00 in west side of tree 9.00 in east side of tree

The above figures suggest that the percentage of bisexual flowers varies from 1.25 to 35.6, and the total number of flowers per panicle varies from about 1,000 to 6,000. The high percentage of perfect flowers in Langra was found to be closely associated with high productivity (49, 57), and in the variety Kalapahar the percentage of bisexual flowers was higher on the west side, indicating some correlation between development of pistillate flowers and light. This last observation needs verification.

From the above it appears that the number of flowers and the percentage of perfect flowers per panicle are varietal characters. Furthermore, the number of male flowers is higher in seedling than in grafted varieties (45), and the number of perfect flowers in the terminal portion of the panicle is greater than in the lower portion (45, 49).

Pollination and Fruit Set. Mango flowers usually open during the night and early morning hours, maximum dehiscence of anthers occurring between 8 A.M. and noon (7, 32, 45, 61).

(i) Pollination. When the flowers begin opening, they secrete honey in considerable quantity which attracts a large number of insects. How far these insects help in cross-pollination is not yet known with certainty. Popenoe (57) states that cross pollination is in all probability uncommon, as most of the stigmas receive pollen from anthers of the same flowers. But Burns and Prayag

(10) write that the flowers are undoubtedly entomophilous and designed for short-tongued insect visitors. Experiments on the effect of excluding pollinating agencies by bagging has shown that there is "practically no fruit set" when they are bagged (45). It has, however, been proved that there is no self-incompatibility, and self-fertilisation by pollination from the same flower is possible (7, 10).

The principal insects observed on the flowers of mango in Florida represent the four orders Diptera, Hymenoptera, Lepidoptera and Coleoptera in the order given regarding the number of visits (10). The regular visitors to mango flowers in Java are the flies, as in Madras (7). Flies belonging to the genera *Psychonosma* and *Pyrellia* are the chief visitors in Poona, India (10).

After the flowers open, the anthers burst and the pollen grains dry up and separate from one another to be removed by the visiting insect or wind to the stigma of the bisexual flowers. Due to the presence of a small percentage of bisexual flowers with very short capitate stigmas, not all the stigmas receive the pollen grains. Naik and Rao (49) reported that under natural conditions about 66% of the flowers remain unpollinated. Mukherjee (42) has also seen that only 3 to 35% of the flowers in a number of grafted varieties are usually pollinated.

(ii) Fruit-Set and Shedding. Thirteen to 28 percent of the bisexual flowers in three very important Indian varieties (Bombai, Langra, Fazli) have been found to set fruit, and only 0.1 to 0.25 percent reached maturity and were harvested (61). Observations by Naik and Rao (49) and Bijhouwer (7) also show that 0.1 percent or less of bisexual flowers develop fruits to maturity for harvesting. It has been observed also that 72 to 87 percent of the bisexual flowers drop unfertilized before fruit-set, and that most of the fertilized flowers drop after fruit-set, leaving only 0.1 to 0.25 percent of the flowers to develop fruits to be harvested.

Experiments at Poona have shown that spraying fruits one-half to one inch in diameter with 25 p.p.m. N.A.A. and 25 p.p.m. 2,4-D in water has helped in checking post-setting drop of Alphonso mango to a considerable extent so as to give 17 to 23 percent more harvest of fruits (22).

(iii) Causes for Low Fruit-Set. The reason for low fruit-set, in relation to the huge number of flowers in each panicle, is primarily the fact that the majority of the flowers (70–90 percent) are male, and secondly that a large number of the bisexual flowers (65–85 percent) remain unpollinated. This is supported by Naik's observation that the percentage of harvested fruits can be increased from 0.25 to 2.4 by artificial pollination.

Low fruit-set, despite the huge number of bisexual flowers, appears, in view of the foregoing, to be primarily a result of failure in pollination and in pollen germination on the stigmas (42). But from a practical standpoint, the question of pollination is relatively unimportant, as success depends on the number of harvested fruits. It has already been stated that 13 to 28 percent of the bisexual flowers are usually fertilised, out of which only 0.1 percent reach harvesting stage. Even if we take the average of fertilised bisexual flowers at 15 percent, only one in 150 fertilised flowers will give mature fruit. There is consequently a huge amount of post fertilisation drop, which is very likely due to deficient nutrition to all the developing embryos. A supply of fresh nutriment to the soil at the proper time and other cultural treatments are the most important factors in achieving high percentages of fruit (42, 57).

To ascertain whether there was any defect in the pollen grains, the writer examined 27 Indian varieties and found that they were mostly healthy, the per-

centage of crushed or crumpled grains being only 1.0 to 12.3. The pollen grains are tricolpate and 23 to 29 μ in size (42). Low fruit-set is not therefore due to any defect in pollen grains, and the prevalence of normal grains is indicated by regular pairing and disjunction of the chromosomes during meiosis in PMC (40).

It has also been suggested that loss in fruit is caused by flowers having abortive pistils incapable of being fertilised (19), but Popenoe did not accept this view, since " examination of many flowers under varying conditions showed very few abortive pistils ". Juliano and Cuevas (27) reported a case of degeneration of the zygote in the Philippine variety Pico.

Fruit Development and Polyembryony

After fertilisation the zygote remains dormant for some time and then gives rise to an embryo. The endosperm is of the nuclear type, and its development follows that of many dicotyledonous plants. It completely fills the embryo-sac and is totally absorbed by the developing embryo at maturity of the seed (27). There are two types of mango as regards embryo development: (a) the Indian type, both seedling and grafted, with only one embryo (monoembryonic) in the seed, which on germination gives rise to a single shoot, and (b) the Philippine, Hawaiian and other seedling races with more than one embryo (polyembryonic) in their seeds which thus produce more than one shoot on germination. Embryo development in mango has been investigated by several workers (3, 5, 25–27), all of whom have observed that the extra embryos in the polyembryonic types are adventitious and originate either from the nucellus or by budding from the cotyledons or hypocotyl.

The time necessary for development of the fruit to maturity after fertilisation differs according to the variety. In early varieties, *e.g.*, Bombai, it is about two months, whereas in the mid-season varieties, *e.g.*, Langra, it amounts to three or three and a half months, and in late varieties, *e.g.*, Fazli, to about four months (61). The period is influenced by temperatures from March to June. If the mean temperature is 21° C. or higher, the fruits ripen early, but if the mean temperature is 20° C. or lower, ripening is delayed considerably (51).

Harvesting, Storage, Ripening and Marketing

Harvesting and marketing methods are very crude throughout the tropics where seedling trees are abundant. Fruits of seedlings are shaken off the trees, gathered into baskets and taken to market, where they are sold loose in bulk with very little attempt at grading. The common practise in India for grafted varieties is to pick the fruits singly by hand or with a metal ring fixed to the end of a long bamboo pole and supporting a net. A sharp edge on the inner side of the ring facilitates dropping the fruit into the net. The stage at which the fruits are to be harvested depends mainly on how long they will have to be stored before consumption. It is advisable to pick fruits for local consumption when they are almost or fully ripe, while for distant transport they may be picked about a week earlier before they soften. Softness to the feel is a reliable index that can be adopted for fruit picking, and in some varieties colour is a good guide (10, 48). The common practise in Bombay for ripening is to spread the fruits in one layer on a bed of mango leaves about four inches thick in a store house and to leave them exposed for two days. They are then transferred to straw or dried grass to ripen in six or seven days (10).

Trials by Burns and Prayag on storage of Alphonso and Pairi varieties show that the former is a better keeper and develops beautiful colour, even when plucked green. It keeps well for 24 days

when suspended in a muslin bag at 77° to 92° F. Tests have been conducted also on four or five varieties at Bombay, Trinidad and other places to determine the proper stage of harvesting for different markets (11, 28, 51, 55, 75).

Wardlaw and Leonard (75) suggested that selection of the stage of maturity for picking depends on the duration and temperature of transport, and on the presence or absence of cold storage facilities during distribution. Where cold storage facilities are available till the fruits reach the consumer, they should be picked just prior to softening; full flavour is thereby obtained and the wastage is minimum. Where such facilities are absent and 20 to 25 days storage is necessary, the fruits should be picked between the stage when they are green but almost fully grown, having shoulders level with stem insertion, and a later stage when the shoulders are raised around the hollow of the stem insertion. On the basis of trials with Alphonso in Bombay, Cheema and Dani (11) recommended that the fruits be harvested with a part of the stock attached so as to keep them longer. The best stage of picking for export to England under cold storage at 45° F. in a ship is the stage at which the shoulders have outgrown the stem end and the fruit is oil green in colour. In England they must endure five or six days in the markets.

Extensive storage experiments were conducted at the Cold Storage Research Laboratory at Kirkee, India, on 28 commercial varieties of India from different provinces (11*a*). The tests indicate that the fruits of stages B (green and mature) and C (green and fully mature) are suitable for cold storage, but the ripe fruits turn brown in cold storage (30–52° F.). There is a correlation between the acid content of the green fruits and their storage life; the latter is long when acidity is high. The effect of packing and wrapping materials and condition of the fruits on ripening during storage have also been determined. Similar experiments on storage and ripening for the important varieties of other regions of the world should be undertaken, as it is well known in India through age-long experience that the best flavour of mangoes can be obtained only by picking at the right stage of maturity and by storing them under specific conditions to ripen. The mango, ripening under such proper conditions, is definitely a delicious fruit par excellence. The fruits usually sold in markets are greatly inferior to such properly matured ones.

Ordinarily bamboo baskets of various shapes and sizes are used for transport to market in India. About 100 fruits are generally packed in several layers between mango leaves in each basket. Trials at Bombay suggest that wooden cases are better than bamboo baskets, since the fruits fetch higher price and the average loss by damage and pilfering is 3.9% instead of 16.1% in bamboo baskets (8).

For export to European markets, Wardlaw and Leonard (75) suggested packing preferably in one layer in a 20-pound tomato box ($5'' \times 16\frac{1}{2}'' \times 17''$) after wrapping the fruits carefully in moisture-retaining papers. For consignments in crates a temperature of 48° F. may be maintained where fruits of grade B have to be kept in storage during a voyage of 15 to 20 days. The temperature for storage should be carefully regulated, since mangoes are subject to low temperature injury, depending on the stage of maturity and period of transport. On removal from cold storage (48° F.) to a temperature of 65 to 70° F., the fruits which have not chilled ripen in four to seven days. If the shipping takes a shorter time, they may be kept at 50° to 60° F.

Burns and Prayag (10) and Cheema and Dani (11) found Alphonso among the Indian mangoes the best type for

export. They suggested packing 12 mangoes (of 24–28 tolas) in two rows in two compartments wrapped in tissue paper, in well-aerated trays 18″ × 10″ × 4″.

Experiments on cold storage at Lyallpur have shown that the Langra mango can be successfully stored in good condition for one month at 32° F. (4).

Trials at Palestine show that after twelve days journey in a fairly hot inner ship's cabin, the Haden fruits reached London in perfect, fully colored, firm but ripe condition. It is claimed that these fruits were the most beautiful mangoes ever seen in London (51).

No reliable marketing data are available on this important fruit. Due to the present scarcity of food and shortage of fruits in India, it fetches a good price and gives a very good return to the grower. Mangoes of good quality, *e.g.*, Langra, were sold in Calcutta in 1951 at three or four fruits per rupee (4.5 rupees = $1). The price was high that "off" year; in "on" years five or six may be sold for a rupee. Mulgoba of Madras or Alphonso of Bombay are sold at similar prices. The return from these varieties would appear to be quite remunerative in future years. According to Bajwa and Musahib-ud-Din (4), the average yield per tree of superior grafted varieties varies from one to three maunds (maund = 82 lb.) of the fruit per tree.

FIG. 7. A mature mango tree with characteristically pendant fruits at Constant Spring, Jamaica. (*Courtesy N. Y. Botanical Garden*).

Utilization of the Fruit

The mango contains much sugar, the percentage of three Indian varieties (Pairie, Alphonso, Totapuri) growing in Hawaii ranging from 11 to 20 percent

with 15 to 20 percent of total solids (57). Pope (44) gives the following composition of eight varieties in Hawaii:

Edible portion, 63.77%
Total solids, nearly 20%
Total carbohydrate, 15.25%
Acidity, 0.122 to 0.379%
Ash, 0.277 to 0.469%
Protein, 0.438 to 1.075%
Fats, 0.032 to 0.530%

Sucrose is the principal sugar, and unripe fruits contain malic and tartaric acids.

Sturrock (71) gives the analysis of other varieties from different areas. The results are more or less similar. Cardena and Morena's analysis of three varieties in Cuba shows that the edible portion varies from 65 to 78%, of which 78 to 81% is water.

An examination of three Indian varieties for vitamins A, C, and D by the Empire Marketing Board shows that the pulp of Alphonso is one of the most potent sources of anti-scorbutic vitamin C; the pulp of the other two varieties (Cawasji-Patel, Shendrya) contains slightly less (54). The rind of Alphonso contains as much C as the pulp. Pulp of all three varieties has as much vitamin A as is present in butter. Vitamin D is not present in any significant quantity. A comparative statement of the minimum dose of a few natural products required to protect a guinea-pig from scurvy for 90 days, given below, shows that a small quantity of mango pulp is sufficient for the purpose:

Mango, Alphonso (pulp or rind)	0.5–1.0 gm.
Cawasji Patel (pulp) ..	1.0–1.5 gm.
Lemon juice	1.0–1.5 cc.
Grape fruit juice	1.0–1.5 cc.
Orange juice	about 1.5 cc.
Apple, Bramley's seedling	3.0 gm.
Apple, Cox's Orange Pippin ..	20.0 gm.

Mustard (46) found that No. 11 variety of Florida had high ascorbic acid content, 107.4 mg. per 100 gm. of fruit. Bhutiani (6) also reported about the vitamin A and C content of eight Indian varieties, among which Langra contains 60.5 mg. of vitamin C per 100 gm. of flesh.

The above experiments as well as a comparative analysis of an apple and a Carabao mango in Barbados, reported by Popenoe (57), suggest that in regard to chemical composition the mango is a better fruit than the apple.

The most important use of mango is as a dessert fruit when ripe, but there are also other food uses in different preparations from ripe and unripe fruits (2, 9, 44, 71, 76). Recipes for the following have been published (44, 71): mango powder (amchur), sweet mango chutney, mango pickle in oil (achar), jam, jelly, mango squash, canned mango, mango preserve (murrabba), mango pulp (ampapar or amsat), marmalade.

Mangoes are now being canned in several countries, but they have not yet found a good market. Preservation in different forms, which may obtain an international market, should be seriously tried because the future of mango depends to a very great extent on such utilization, as is true of other fruits. This is particularly important for India and any other tropical countries where the mango may be important. The temperate fruits have already secured a good market in their canned and other preserved products. The mango, which has equally good food value and flavour, can also find a favourable market, provided good and cheap methods of preservation on a commercial scale are developed. The over-production of fruits in "on" years can thereby be used up profitably. One great handicap in the successful utilization of this fruit is the old method of transport in India. Location of orchards in interior areas without any arrangement for cold storage and fast transport to the cities does not allow the fruits to come to market in good condition and to ripen with good flavour.

FIG. 8. A flowering branch of mango in Costa Rica. (*Courtesy N. Y. Botanical Garden*).

The orchards have also no arrangement for canning or other up-to-date methods of preservation so that the excess production can be kept for future use.

Apart from the flesh of the fruit, the thick cotyledons in the mango stones have recently attracted attention in India as a food for human consumption and for cattle in times of food scarcity. Its food value is similar to that of rice, and it contains essential proteins, 5.56%; fat, 16.1%; carbohydrates, 69.29%; and small quantities of calcium, phosphorus, iron and other minerals (44).

In Celebes part of the surplus mango crop is turned into vinegar; manufacture of a kind of brandy is also possible. Mango flowers are eaten by the Siamese, and very young purple-brown leaves are consumed with rice by the Javanese (9). The seed, bark and young fruits have some medicinal value (36), and the bark and leaves yield a yellow dye suitable for dyeing cotton, silk and wool. The wood is extensively used in India for cheap furniture, planking, floor and ceiling boards, tea-chests and other box and crate works, boat-building, agricultural implements, and recently for plywood manufacture (73).

Pests and Diseases

Several insects and fungal diseases attack mango fruits, leaves and other parts. The fungi cause less damage than the insects while the fruits are on the tree, but they cause rotting during storage, sometimes as a secondary infection.

Insects. The most injurious insects of the mango belong to the order Diptera, followed closely by those of the Homoptera. The Mediterranean fruit-fly (*Ceratitis capitata* Wied) and the West Indian fruit-fly (*Anastropha fraterculus* Wied) do considerable damage to the fruits in Hawaii, West Indies, Puerto Rico and other areas (28, 51, 55, 71). The mango fruit fly (*Dacus ferrugineus* = *Dacus zonatus* = *Chaetodacus ferrugineus* Fabr.) is a serious pest in India, doing considerable damage in some seasons (10, 48). There are also reports of attack from Queensland and Mexican fruit-flies (71).

The mango hoppers (*Idiocerus atkinsonii* Leth., *I. clypealis* Leth., and *I. niveosparsus* Leth.) are serious in India to the inflorescence, causing a loss of 25–90%. Control measures of sulphur dusting or spraying with fish oil resin soap have been suggested (48, 58, 74, 77).

The mango weevils (*Sternochetus mangiferae* Fabr. and *S. gravis* Fabr.) are serious pests to fruits in Hawaii and in some parts of India. The only remedy is to destroy all drops and seeds by fire (10, 48, 55, 77).

A number of caterpillars are found destroying the young leaves in India, Malaysia and Philippines. They are not so injurious for old trees, but they cause great damage to the young grafts in nurseries (10, 48, 58, 71). A number of scale insects, which cause little damage, has been reported by Wester (77) and Sturrock (71).

Fungal Diseases. The most troublesome fungus, common wherever mango is grown, is *Colletotrichum gloeosporioides* Penz which attacks the flowers and causes anthracnose or blight. It is serious in tropical America, Hawaii and in South India (10, 48, 55, 57, 60). The recommended control method is to spray thoroughly with Bordeaux mixture two or three times two weeks before the flowers open.

Black blight or sooty mould, caused by *Capnodium mangiferum* Cooke and Broome, *C. ramosum* Cooke and *Meliola mangifera* Earlle growing on the "honey dew" secretions of leaf hoppers or scale insects on the leaves, produces a mold at times so dense that it interferes with photosynthesis. It is common in India and elsewhere.

Diseases of minor importance are mango powdery mildew (*Oidium man-*

giferae Berthet), pink disease (*Corticium salmonicolor*), black stem (*Rhinocladium corticolum* Mass.) and red rust (*Cephaleuros virescens* Kunz.).

Other Diseases and Pests. Black tip of mango recently attracted attention in India when it was prevalent in Bihar and U.P. It first appears as incipient aetiolation at the distal end of the fruit. The aetiolated area increases in size and is followed by greyish-brown spots which coalesce to form a continuous necrotic area. As the disease advances, a considerable part of the fruit is destroyed. Investigations by Das Gupta and his collaborators (12–15, 17) indicate that this necrosis cannot be attributed to any fungal or bacterial organism.

Woodhouse (79) was the first to assert that the disease is prevalent in orchards near brick-kilns, and others (52) have supported this view, one of them (62) inducing the disease by burning coal in orchards. Injections of healthy mangoes with sterile mango juice through which brick-kiln fumes had been passed for some time, as well as with the gas dissolved in ether and chloroform, produced necrosis in 50% of the fruits. This suggests that the constituents of brick-kiln gas are the primary causal agencies of the disease, but how is not yet known. The gases may be absorbed directly by the fruits or by other regions and subsequently translocated to them.

Die-back disease causes the leaves to fall and the twigs to dry up; an entire branch or a part displays dead leafless twigs arising out of the green foliage. *Botryodiploidia theobromae*, *Phoma* sp. and *Fusarium* sp. are three fungi found associated in the affected parts, but the pathogenicity of only the first has been definitely established by inoculation experiments. The predisposing factor for this disease may be high summer temperature which affects the vitality of the plants and enables the pathogen to attack (16).

FIG. 9. Fruit of mango at Bayeux, Hayti. (*Courtesy N. Y. Botanical Garden*).

A bacterial disease (*Bacillus mangiferae*) causing fruit-rot is reported from South Africa (57).

Bunchy or abnormal inflorescence involves shortening and thickening of the inflorescence axes with consequent crowding of the flowers. Such deformities seldom bear any fruit. The disease has been known for many years and has been spreading in recent years. As no fungus or insect has been found associated with it, Sattar (60) suggests that it may be of virus origin or due to some physiological disorder.

Cytogenetics and Breeding

Information on the cytogenetics of mango is rather meagre. Till recently nothing has been known except the chromosome number in only one species, *Mangifera indica*. Investigation by Mukherjee (39, 40) on two wild species, *M. sylvatica* and *M. caloneura*, and 24 wild and grafted varieties of *M. indica* shows that all of them have $2n = 40$ and $n = 20$ chromosomes. The somatic chromosomes vary from 0.4 to 2.0 μ in length, and eleven types can be distinguished among them on the basis of their mor-

phology. Analysis of the karyotypes shows that the varieties of mango and of allied species differ from one another mainly in the assortment of these eleven chromosome types.

Although no polyploid series of chromosome numbers has been found in the cultivated varieties of mango and in allied species, their polyploid nature is indicated by the high number of somatic chromosomes, a correspondingly high number of nucleolar chromosomes, regular pairing and disjunction of chromosomes during meiosis, absence of any multivalent formation and good fertility. The suggested allopolyploidy originated most probably through amphidiploidy, and differentiation of the numerous varieties then took place primarily through gene mutations, the selected types being preserved under cultivation by grafting. Since compatibility between varieties is great because of close similarity in chromosome morphology, intervarietal hybridisation has occurred freely in nature as another important process in the production of varieties.

Previous records show that successful crossing was made between the varieties Cawasji-Patel and Pairie as early as 1915 in Bombay (10). Recently intervarietal crossing to combine the good qualities of different varieties has been tried in America and at the fruit research stations at Madras and Bihar in India. The crosses have been successful and the results appear to be promising, but it is as yet too early to know the quality of these hybrids as regards inheritance of economic characters. Many more crosses should be attempted to assess their merits. This is likely to be an important line of work for the improvement of mangoes, as any chance hybrid possessing desirable qualities can be easily multiplied by grafting.

Sturrock (71) reports a number of crosses growing successfully in America. One of these is between Haden and Carabao, another between Saigon and Amini. Pope (55) has reported a number of hybrids from Hawaii. Hybrids between Himayauddin and Neelum, Jehangir and Suvarnarekha, Jehangir and Neelum, Allampur Beneshan and Neelum have been recently reported from India (50).

Classification and Varieties

All mangoes belong to a single species, *Mangifera indica* L. They can be broadly grouped in two categories: seedling races, both wild and cultivated; and horticultural varieties, propagated by budding or other grafting.

The seedling races are mainly of two types: monoembryonic and polyembryonic. Those in India are monoembryonic, except a few from the West Coast of South India (35), but the seedlings in the Philippines, Indochina and other countries are predominantly polyembryonic. Information about the cultivated seedling races of Indochina, the Philippines, the Pacific islands and America is available in Popenoe's Manual (57). The seedling races of India have not been properly studied as yet, as the cultivated plants in the mango orchards of this country are mostly grafted varieties.

Little knowledge about the fruits of the wild seedling races of India was available till recently, except what is usually given in floras. Investigation by the author has shown that the wild mangoes in India bear fruits which possess a variety of shapes, as are found in the cultivated varieties, and are sometimes of similar size. It appears, therefore, that selection by man has played an important role in the production of the improved cultivated varieties from the various wild types growing in India (38).

Though the grafted varieties of mango had been under cultivation in India for 400 years or more, an attempt to describe the varieties with technical botanical language was first made in 1900

by Maries (33) who collected about 500 varieties from India. Watt (76), Woodhouse (78), Burns and Prayag (10) and Popenoe (57) subsequently published descriptive lists of mango varieties and suggested some methods of grouping them. Woodhouse's contribution is most important, as he, describing 40 varieties of Bihar, first suggested the characters of the fruit with which to distinguish the varieties. Burns and Prayag accepted similar characteristics and described more thoroughly 89 varieties of mango from Bombay. They grouped them into three cohorts—round-fruited, long-fruited and indefinite. Classification by these workers was on the basis of fruit characters only and therefore is somewhat artificial, but it has helped in cataloguing the varieties under cultivation. Those of the Philippines, Puerto Rico and Hawaii have been described elsewhere (28, 55, 77).

Popenoe published a descriptive list of 300 varieties from all parts of the world, and subsequently classified them into four groups—Mulgoba, Alphonso, Sandersha, Cambodiana—on the basis of fruit characters, colour of the panicle axis and laterals, pubescence on the panicle branches and number of embryos in the seed (57). Panicle characters were thus used for the first time by him. Subsequently Mukherjee (35) made a thorough study of the range in variability and published a tabulation of the following characters in 72 varieties from Bengal, Bihar and U.P., as well as a key for the identification of these varieties:

Tree Habit
Leaf
  Colour at emergence
  Colour at maturity
  Margin
  Size
Inflorescence
  Colour of panicle branches
  Pubescence of panicle branches
  Length
  Presence or absence of leafy bracts
Flowers
  Size
  Ridges on petals (colour and pattern)
Fruit
  Detailed description

The foregoing was the first endeavor to employ vegetative characters. The only previously published key for identification of mango varieties is that of Sturrock and Wolfe (72) for 38 varieties of Florida, based on fruit characters exclusively.

Simultaneously work was conducted by Naik and Gangolly (50) on a classification of South Indian mangoes, also employing vegetative characters in addition to the most important features of the fruit. They found that variations in the apex and in the inrolling of mature leaf margins are of significant classificatory value. They described 335 varieties of South India, including ten polyembryonic varieties of the West Coast, and arranged them in three groups—fruits roundish, fruits intermediate, fruits markedly long—which differ from the groups of Mukherjee (1948)—round fruited, ovate-oblong fruited, long fruited—only in terminology. Subsequently they divided their three groups into six cohorts, probably following Burns and Prayag, by dividing each group by the characters—" Fruits with missing to a point beak " or " Fruits with distinct to prominent beak ". I consider the wording " beak prominent ", " beak absent or almost imperceptible " as more appropriate for these characters.

Description of mango varieties in the remaining areas of India and in other parts of the world according to Mukherjee's scheme and classifying them by the key given by the writer or by Naik and Gangolly will definitely help in standardising them and in elucidating the relationship between the varieties. It will also clarify the origin of the varieties and will help in revealing the identity of varieties, incorrectly known at pres-

ent in different countries or even in different regions of the same country under more than one name. The more important commercial varieties from India and other places are:

Grafted Indian Varieties: Pairie, Alphonso, Cawasji-Patel, Mulgova, Baneshan or Banganapalle, Rumani, Neelum, Bangalora or Totapuri or Sundersha, Langra, Fazli, Sunder Prosad, Golap Khas, Zardalu, Aman Dasheri, Kishenbhog, Bombay, Himsagar, Gopalbhog, Bhuto Bombai, Shadwala, Himayuddin, Safeda.

Seedling Races: Indochina—Cambodiana (Xoai voi) and Mekongensis.
Philippines—Carabao and Pico.
Cuba—Chino and Biscochuelo.
West Indies—Mango macho or No. 11, Manga blanca and amarilla.

The grafted varieties of regions outside India have been directly or indirectly introduced from India, or evolved locally from some Indian parent.

Problems of Future Improvement

Commercial orchardising of mango outside India has not yet been successful, and the fruit has not yet received the attention of growers that it deserves. The reason, according to one authority, referring to Florida, may be that " The average land owner has been more interested in the quicker turnover of the annual crops and has not been willing to invest for the slower returns from orchardising " (71). I am more inclined to attribute the situation to the failure of most of the good grafted Indian varieties outside India, and to the irregular bearing habit of the good varieties which causes failure of the crop in alternate years. Furthermore, the Indian mangoes have been especially affected by insect pests and anthracnose infection in the Philippines, Hawaii, Puerto Rico or Florida where they were introduced. Thirdly, low resistance to frost is significant in subtropical areas.

In India, its original home, mango has not been accorded as much attention as it merits. Most of the varieties under cultivation here are the products of selection and grafting undertaken 300 or more years ago. Although some hybridisation work has been recently undertaken, the hybrids have not yet reached the growers. The numerous seedling trees growing in the country and the trees in orchards are usually left without any attention for cultural treatments. Another handicap in its development in India and elsewhere may be the want of successful and cheap methods for canning or other methods of preservation of fruits without seriously affecting flavour. Apple, pineapple and other fruits have been the recipients of greater attention in this respect. This neglect has led to the inevitable consequence of wastage of fruits during " on " years when there is overproduction during a short period. The old fashioned methods of preservation, packing and marketing, still in vogue in India, lead to wastage during transit and marketing, and to deterioration in quality.

Future work for improvement of mangoes should pursue the following objectives:

(1) A thorough description and enumeration of the varieties, both seedling and grafted, in different countries of the world. Particular attention should be paid to their economic characters.

(2) Determination of the varieties which are suitable under different cli-

matic conditions and which may be of commercial importance. Sturrock (71) suggests that the future orchard type of mangoes for tropical America and the West Indies should have some of the characteristics of the Philippines or of the Indochina types to lend a measure of adaptability to weather conditions resistance to frost, particularly in new types for Florida; extra earlyness and extra lateness in fruiting. The varieties which possess these qualities and which thus appear suitable for transmitting them in breeding work may be grouped as follows: For inducing regular bearing habit: Desavaltheya mamidi, Enamandala theya mamidi, Peta theya mamidi (48), Neelum, Rumani, Allipasand (49), Baramasia and Fazli (63) for India, whereas in America Amini, Bennett, Sandersha and the Indochina and Philippine types may be used (71). For high keeping quality the Indian variety Alphonso is suitable; for winter hardiness, Bombay Yellow, Borsha, Gola, Faizan and Sandersha (71). For resistance to anthracnose or fruitfly, Bennett, Bom-

FIG. 10. A native market under a mango tree at Bayeux, Hayti. (*Courtesy N. Y. Botanical Garden*).

(wet season), especially at the time of flowering.

(3) Breeding of new mangoes through inter-varietal and interspecific hybridisation (37) with a view particularly to producing new types with the following qualities: regular and prolific fruit production; resistance to anthracnose and other diseases, and to fruitfly and other insect pests; high keeping quality of fruits under storage, and slow ripening;

bay Yellow, Chino, Faizan, Gola, Sandersha, Cambodiana, Saigon and other Indochina and Philippine types may be used. For production of extra early or extra late varieties Olour, Bennett, Alphonso, Mulgova, Mundappa, Neelum, Rumani, Allipasand, Baramasia, Fazli, etc. (48, 63). Chino, Amini, Cambodiana, Pico, Saigon, Faizan, Gola or Sandersha (71) may be used as parents.

(4) Finding suitable pollenizer varieties for interplanting in orchards to increase fruit-setting.

(5) Attention to cultural, manuring or other methods for induction of flowering every year. Since cultural requirements of the different varieties are little known, investigations should be carried out in this problem.

(6) A thorough study of the seedling varieties in India, which are completely unknown, to determine their economic qualities. Simultaneously investigations should be made regarding the occurrence of polyembryony among Indian varieties. It is interesting to note in this connection that careful observations have shown that Langra, Bombai and other varieties, generally regarded as monoembryonic, sometimes produce more than one shoot (65).

(7) Investigation to improve the methods of propagation, particularly to make budding successful and easy for common growers. An important cause of the predominance of seedling trees in different parts of the world is the high price of grafts produced by inarching, the prevailing method of vegetative propagation. The stock and scion problem in mango also deserves further investigation as there are few experimental data on this problem.

(8) Determining proper methods of picking, packing and ripening under storage at different temperatures or during transit of the important varieties of different areas. Determination of the picking stage in relation to the period required to reach the market is very necessary for getting a good price for the fruits, as their flavour depends very much on proper ripening during storage and transit. Except for Alphonso and a few other varieties, very little is known in this respect.

(9) Evolving successful methods of preserving the fruits in different forms at cheap and competitive rates for home consumption and international markets, and determination of the qualities of different varieties to be used for such purpose.

Literature Cited

1. Alcala, P. E., and San Pedro, A. 1935. Bud differentiation in smudged trees. Philip. Agr. **24**: 27–48.
2. Ann. fruit preservation number. Punjab Fruit Jour. 1944.
3. Arndt, C. H. 1935. Notes on polyembryony and multiple shoots from the seed in *Mangifera indica*. Am. Jour. Bot. **22**: 26.
4. Bajwa, B. S., and Musahib-ud-din. 1946. The present status of mango industry in the Punjab. Punjab Fruit Jour. **10**: 1–7.
5. Belling, J. 1930. Mango. Fla. Agr. Exp. Sta., Ann. Rep: 110–125.
6. Bhutiani, R. C. 1946. Vitamin content of the mango. Punjab Fruit Jour. **10**: 112–115.
7. Bijhouwer, A. P. C. 1937. Een bijdrage tot de kennis omtrent het bloeien en het vruchtdragende vernogen van den Mangga (*Mangifera indica* L.) [The flowering and fruiting habits of the mango].
8. Bombay Dept. Agr. 1930. Lft. 2.
9. Burkill, I. H. 1935. A dictionary of the economic products of the Malay Peninsula. Vol. 2: 1401–1406.
10. Burns, W., and Prayag, S. H. 1921. The book of the mango. Dept. Agr., Bombay, Bull. 103, 98 pp.
11. Cheema, G. S., and Dani, P. G. 1938. Report on the export of mango to Europe in 1932. Dept. Agr., Bombay, Bull. 170.

11a. ———, Karmaker, D. V., and Joshi, B. M. Investigation on the cold storage of mangoes. Indian Coun. Agr. Res., Misc. Bull. 21. 1939. Indian Jour. Agr. Sci. **20**: 259–325. 1950.

12. Das Gupta, S. N., and Sinha, S. 1944. Studies, etc. IV. Investigation into the

pathological histology of fruits affected with "Black-tip" disease with a note on the anatomy of the fruit. Proc. Nat. Acad. Sci. India **14**: 102–108.

13. ——— and Verma, G. S. 1939. Studies in the diseases of *Mangifera indica* L. I. Preliminary observations on the necrosis of the mango fruit with special reference to the external symptoms of the disease. Proc. Indian Acad. Sci. **9**: 13–28.
14. ——— and ———. 1940. Studies in the diseases of *Mangifera indica* L. II. Effect of injecting healthy mango fruits with extract from naturally occurring necrotic mangoes. *Ibid.* **12**: 95–108.
15. ———, ——— and Sinha, S. 1941. Studies, etc. III. Investigation into the effect of sulphur dioxide gas on the mango fruit. *Ibid.* **13**: 71–83.
16. ——— and Zachariah, A. T. 1945. Studies, etc. V. On the die-back disease of the mango tree. Jour. Indian Bot. Soc. **24**: 101–118.
17. ——— et al. 1950. Necrosis of the mango fruit. Curr. Sci. **19**: 153.
18. De Candolle, A. P. 1884. Origin of cultivated plants.
19. Dudgeon, W. 1929. The morphology of *Mangifera indica* L. Proc. Indian Sci. Congr.: 230.
20. Edwards, B. 1793. History of the West Indies.
21. Firminger, T. A. C. 1874. A manual of gardening for Bengal and Upper India.
22. Gokhale, A. V., and Kanitkar, U. K. 1951. Fruit drop in Alfonso mango and its control. Proc. Indian Sci. Congr.: 151.
23. Higgins, J. E. 1906. The mango in Hawaii. Hawaii Agr. Exp. Sta., Bull. 12.
24. ———. 1910. Shield budding the mango. *Ibid.* Bull. 20.
25. Juliano, J. B. 1934. Origin of the embryos in the strawberry mango. Philip. Jour. Sci. **54**: 553–563.
26. ———. 1937. Embryos of Carabao mango (*Mangifera indica*). Philip. Agr. **25**: 749–758.
27. Juliano, J. B., and Cuevas, N. L. 1932. Floral morphology of the mango (*Mangifera indica* L.) with special reference to the Pico variety from the Philippines. Philip. Agr. **21**: 449–472.
28. Kinman, C. F. 1918. The mango in Puerto Rico. Puerto Rico Agr. Expt. Sta., Bull. 24.
29. Lanuza. 1939. Notes on bud differentiation in Carabao mango (*Mangifera indica* L.). Philip. Jour. Agr. **10**: 131.
30. Leley, V. K., Narayana, N., and Daji, J. A. 1943. Biochemical studies in the growth and ripening of the Alphonse mango. Indian Jour. Agr. Sci. **13**: 291–299.
31. Maheshwari, P. 1934. The Indian mango. Curr. Sci. **3**: 97–98.
32. Mallik, P. C. 1951. Morphology and biology of the mango flower. Proc. Indian Sci. Congr.: 155.
33. Maries, C. 1901–2. Indian mangoes. Jour. Royal Hort Soc. **26**: 755–770.
34. Miquel, F. A. G. 1859. Flora van Nederlandsch Indie. Vol. 1(2): 627–634.
35. Mukherjee, S. K. 1948. The varieties of mango (*Mangifera indica* L.) and their classification. Bull. Bot. Soc. Bengal **2**: 101–133.
36. ———. 1949*a*. A monograph on the genus *Mangifera* L. Lloydia **12**: 73–136.
37. ———. 1949*b*. The mango and its relatives. Sci. and Cult. **15**: 5–9.
38. ——— 1950*a*. Wild mangoes of India. Sci. and Cult. **15**: 469–471.
39. ———. 1950*b*. Cytological investigation on the mango (*Mangifera indica* L.) and the allied Indian species. Proc. Nat. Inst. Sci., India **16**: 287–303.
40. ———. 1950*c*. Mango, its allopolyploid nature. Nature **150**: 196–197.
41. ———. 1951*a*. The origin of mango. Indian Jour. Genet. and Plant Breed. **11**: 49–56.
42. ———. 1951*b*. Pollen analysis in *Mangifera* in relation to fruit-set and taxonomy. Jour. Indian Bot. Soc. **30**: 49–55.
43. Musahib-ud-din. 1946. Fruit bud differentiation in mangoes in the Punjab. Punjab Fruit Jour. **10**: 30–31.
44. ——— and Bhutiani, R. C. 1946. Mango products. *Ibid.* 42–47.
45. ——— and Dinsa, H. S. 1946. The floral count and fruit-set studies in some of the North Indian mangoes. *Ibid.* 35–42.
46. Mustard, M. J. 1945. Mangoes and guavas as sources of ascorbic acid. Proc. Ann. Meet. Florida State Hort. Soc. **58**: 187–190.
47. ——— and Lynch, S. J. 1946. Flower bud formation and development in *Mangifera indica*. Bot. Gaz. **108**: 136–140.
48. Naik, K. C. 1941. South Indian mangoes. Agr. Dept. Madras, Bull. 24.
49. ——— and Rao, M. M. 1943. Studies on blossom biology and pollination in mangoes (*Mangifera indica* L.). Indian Jour. Hort. **1**: 107–119.
50. ——— and Gangolly, S. R. 1950. A monograph on classification and nomenclature of South Indian mangoes. (Govt. Press, Madras) 311 pp.
51. Oppenheimer, C. 1947. The acclimatisation of new tropical and subtropical fruit

trees in Palestine. Agr. Res. Sta., Rehovot, Palestine, Bull. 44.
52. Pal, N. L., Chatterjee, U. N., and Ranjan, S. 1937. Effect of gases from brick kilns on mango crops. Proc. 24th Indian Sci. Congr.: 270–271.
53. Paul, W. R. C., and Guneratnam, S. C. 1939. Propagation of the mango in Jaffa. Trop. Agr. **16**: 158.
54. Perry, E. O. V., and Zilva, S. S. 1932. Empire Marketing Board preliminary report on vitamin content of the mango.
55. Pope, W. T. 1929. Mango culture in Hawaii. Hawaii Agr. Exp. Sta., Bull. 58.
56. Popenoe, W. 1917. The pollination of the mango. U. S. Dept. Agr., Bur. Plant Ind., Bull. 542.
57. ———. 1932. Manual of tropical and subtropical fruits.
58. Rahman, K. A. 1946. Important insect pests of the mango and how to combat them. Punjab Fruit Jour. **10**: 52–56.
58a. Roy, R. S., Mallik, P. C., and De, B. N. 1951. Manuring of the mango (*Mangifera indica*). Proc. Am. Soc. Hort. Sci. **57**: 9–16.
59. Rumphius, G. E. 1741. Herbarium Amboinense. Vol. 1: 93–99.
60. Sattar, A. 1946. Diseases of mango in the Punjab. Punjab Fruit Jour. **10**: 56–58.
61. Sen, P. K. 1939. Fruit Res. Sta., Sabour, Bihar, Ann. Rep. 1938–39.
62. ———. 1941. "Black-tip" of the mango. Sci. and Cult. **7**: 56.
63. ———. 1943. The bearing problem of the mango and how to control it. Indian Jour. Hort. **1**: 48–71.
64. ———. 1946. You can get a full crop of mango every year. Punjab Fruit Jour. **10**: 31–34.
65. ——— and Mallik, P. C. 1940. Embryo of the Indian mangoes (*Mangifera indica* L.). Indian Jour. Agr. Sci. **10**: 750–760.
66. ——— and ———. 1941. The time of differentiation of the flower bud of the mango. *Ibid.* **11**: 74–81.
67. Sen, P. K., and Roy, P. K. 1945. Mineral nutrition of the mango. Proc. Indian Sci. Congr. Pt. III: 23.
68. Singh, L., and Khan, A. A. 1939. Relation of growth to fruit bearing in mangoes. Indian Jour. Agr. Sci. **9**: 835–856.
69. ——— and ———. 1942. Mango budding in situ—A new technique likely to revolutionize mango industry. Punjab Fruit Jour.
70. Singh, S. 1946. Propagation of the mango in the Punjab. Punjab Fruit Jour. **10**: 8–9.
71. Sturrock, D. 1944. Notes on the mango (published in cooperation with the Atkins Institution of the Arnold Arboretum, Cienfuegos, Cuba). 122 pp.
72. Sturrock, T. T., and Wolfe, H. S. 1944. A key to Florida mango varieties. Proc. Fla. State Hort. Soc.: 175–180.
73. Trotter. 1941. The common commercial timbers of India and their uses. P. 129–130.
74. Wagle, P. V. 1929. The mango hoppers and mildew and their control. Poona Agr. Coll. Mag. **21**: 170–173.
75. Wardlow, C. W., and Leonard, E. R. 1936. The storage of West Indian mangoes. Bull. Low Temp. Res. Sta., Imp. Coll. Trop. Agr., Trinidad, 1–47.
76. Watt, G. 1891. Dictionary of the economic products of India. Vol. 5: 146.
77. Wester, P. J. 1920. The mango. Philip. Bur. Agr., Bull. 18.
78. Woodhouse, E. J. 1909*a*. The mangoes of Bhagalpur. Quart. Jour. Dept. Agr. Bengal **2**: 168–187.
79. ———. 1909*b*. The mangoes of Bihar. *Ibid.* **2**: 283.

Utilization Abstract

Tobacco Flavoring. The natural aroma and flavor of cured tobacco are not sufficient to render it the attractive narcotic that it is in cigarettes. Other materials must be added during manufacture to achieve that attractiveness. Coumarin, with a vanilla-like odor and obtained from tonka beans of South America, was long the principal agent for this purpose, but the natural product is now largely replaced by synthetic coumarin. Powdered leaves of deer's tongue, known also as hound's tongue and Carolina vanilla, have also long been used. "Additional flavorings used by American tobacco manufacturers include cocoa, chocolate, ginger, cinnamon, molasses, rum, brandy, maple syrup, various esters, angelica, oil of anise, oil of juniper, oil of cloves, honey, licorice and sugar, the last two leading in the quantities used". (J. E. Brooks, *The Mighty Leaf*, p. 299).

Broomcorn—*The Frontiersman's Cash Crop*[1]

About 50,000,000 brooms are manufactured annually in the United States from the long fibrous branches in the inflorescences of this corn-like crop.

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Introduction

Broomcorn culture was carried across the United States to new western lands by successive waves of pioneers. This march continued from about 1805 to 1930, when our last farming frontier was reached. Pioneer farmers liked broomcorn because its high value per pound made it feasible to haul or ship the brush long distances. Few domestic industrial crops, *e.g.*, hops and mint, move so far from farm to factory. High-quality broomcorn brush has brought growers up to 525 dollars a ton during periods of scarcity and high economic price levels. Poor brush, even in depression or panic periods, usually sells for 25 to 40 dollars or more per ton.

Broomcorn is valuable because it makes better brooms than any other product yet discovered. The fine seed branches near the tip of the fiber help to gather dust and lint. The flexibility and resilience of its fibers are unexcelled, and few other fibers equal it in wearing quality. The drought resistance of the plant made the crop a favorite of Great Plains settlers from Nebraska southward. Since the brush is harvested before the seed is ripe, broomcorn may partly evade a drought that ruins a grain crop. Despite its drought resistance, broomcorn thrives best in the rich well-watered prairie and river bottom lands. Broomcorn grows well in humid sections, but the quality of the brush may be injured by wet weather at harvesttime.

Not all brooms are made from broomcorn. Madame Neanderthal Q. Cavewoman doubtless used a branch of a tree to sweep dinosaur bones from the dirt floor of her subterranean dwelling. People of later ages made "besoms" for sweeping by tying a bundle of twigs, straw or sedge stems to a stick. Hemlock, birch or elm boughs tied together served early American colonists. They also made small brooms by shaving or splintering the end of a hickory stick. Others tied up a bundle of the grass, broomsedge (*Andropogon virginicus*). By 1200 A.D. Britons had learned to use the leathery twigs of the yellow-flowered leguminous broom plant belonging to the genus *Cytisus* (or *Genista*). As a result, the besom came to be called a broom some four centuries later. Some brooms at present are made from vegetable fibers such as piassava, palmyra stalks and "rice root" obtained from the tropics[3], as well as from rice straw.

Cordgrasses (*Spartina* spp.), rice straw, hickory splints and shredded leaves of the Yucca-like plants, bear grass (*Nolina* spp.), are used as low-priced inside fillers in American broomcorn brooms when the latter fiber is scarce and high priced.

Broomcorn Uses

Broomcorn is used almost exclusively for sweeping and brushing but it supplies certain other needs. The housewife of a

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[3] See "Brush-Making Fibres", by R. H. Kirby, Econ. Bot. 4(3): 243–252. 1950.

half-century ago used a broomstraw to test a cake in the oven to see whether it was fully baked. Grandpaw knew that a broom straw makes a fine pipe cleaner. Broomcorn is used to top the hurdles at dog racing courses. A wisp of broomcorn panicles twisted in the hands produces a noise similar to that from a crackling fire. Radio, television and motion picture engineers use this device for making an imaginary fire sound realistic. Coarse broom fibers serve as stems for artificial flowers. Broomcorn stalks have long been known to be suitable for the manufacture of fiber board and paper, but they are not so used industrially at present. The stalks, when plowed under, return an abundance of organic matter to the soil.

Brooms used in many countries are made mostly from piassava, straw, grass, sedge, twigs or other materials, instead of broomcorn. The United States produce about as much broomcorn as the rest of the world combined. France, Argentina, Hungary and Italy are the chief foreign producers, each of these countries producing from 3,000 to 12,000 tons in a year. The latter three countries, along with the United States, are the chief exporters. The crop in France, called "sorgho á balaise", is grown chiefly in the Rhone and Garonne valleys, in the vicinity of Marseilles and Bordeaux. The Italian crop is grown mostly in the vicinity of Leghorn in Tuscany, with some also near Venice, Florence and Genoa. The crop in Hungary is grown in the southern half of that country. In Argentina broomcorn, or "maiz de guinea", is produced by many small growers in the vicinity of the larger cities. There it is planted from September to November on land from which a winter crop of wheat, flax or barley has been harvested. Some broomcorn is grown also in southern Brazil, Uruguay, Australia, Yugoslavia and Roumania, and small quantities are raised in many other countries, including Mexico. In Australia the crop is called "broom millet".

The United States normally has exported from 2,000 to 5,000 tons of broomcorn yearly, chiefly to Canada, Cuba and Mexico. Brooms are exported to these countries and also to Europe. Foreign broomcorn usually is of lower quality than much of that grown in the United States, chiefly because growers allow the seed to ripen before harvesting the brush. That often results in reddened harsh fiber. Much of the European fiber also is long and coarse because of thin planting in the field. Many Europeans prefer a broom with longer fibers than those in the American household broom.

Broomcorn is imported into the United States in years when the domestic crop is short, mostly from Argentina, Italy and Hungary. Imported brush is subject to a tariff and also must be consigned to New York or Boston where facilities are available for steam fumigation of the brush in the ship's hold before it is unloaded. This fumigation is to kill any European corn borers present, a pest which originally reached the United States in some European broomcorn arriving in Boston. The brush shipped to this country usually is cut from the "handle" to reduce weight and to eliminate the handles that may harbor overwintering borers.

Broomcorn is grown on some 200 to 300 thousand acres annually in the United States on which are produced from 30 to 50 thousand tons of cured brush. From 1100 to 1200 household brooms, each containing one to one and one-fourth pounds of fiber, are made from each ton of brush. Nearly a third of the weight of an average bale of broomcorn is discarded as sortings, trimmings, seeds, trash and wire bands.

No home is complete without a broom, even if used only for sweeping the porch,

kitchen floors, steps, walks, garage or basement. Before waxed floors, scatter rugs, vacuum cleaners and floor dust mops were in common use, the broom was the device for sweeping the wall-to-wall carpeted floors. Despite these household changes, broomcorn consumption has decreased less than 20 percent in the past 35 years. Broomcorn brooms are not confined to the home. They are used in warehouses, stores, factories, steel mills, smelters, cotton mills and barns.

FIG. 1. A field of Standard broomcorn.

The steel floors of steel mills constantly must be swept free from grit and cinders. Such particles will stick to a hot sheet or bar should it touch a dirty floor and thus create a flaw in the hot steel when it passes through the next set of rolls. Lint must be swept from cotton mill floors to reduce fire hazards and maintain morale. Our armed forces need brooms not only to clean quarters but also to keep men busy during slack periods. Wintertime finds hundreds of men with broomcorn brooms in railroad yards sweeping snow out of the rail switches to keep them from freezing fast.

Traditionally, no witch is complete without a broom.

The Plant and Its Origin

The origin of broomcorn is obscure. It is a specialized type of the sorghum plant (*Sorghum vulgare*). Sorghum apparently originated in central Africa and was carried to countries bordering the Mediterranean. Men or women of the Dark Ages used long-branched sorghum panicles for making brooms and doubtless began to select heads for planting that had the longest panicle branches. They continued this selection for many generations until broomcorn was evolved. The broomcorn plant was first described in Italy late in the 16th Century. The Chinese, after introducing sorghum about the 13th Century, likewise developed a broom kaoling (sorghum) with long

fibers that approach those of broomcorn. The present-day broomcorn plant has a nodding panicle with long fibrous branches borne at the top of a stalk that is from three to 15 feet in height. The stalks have some resemblance to a cornstalk. In fact, the original draft of an official order, issued by the War Production Board during World War II, authored by a Bronx barrister, defined broomcorn as "a kind of corn without any ears on it".

The broomcorn plant (*Sorghum vulgare* var. *technicum*) is a tall coarse annual grass having solid dry, pithy stalks with eight to 15 nodes and leaves above the ground level. The upper internode or peduncle is eight to 18 inches long. At its top is a series of closely compressed panicle nodes from which the fibers arise. The fibers, usually 12 to 24 inches long, are branched toward the tip, and the flowers and seeds are borne at the tips of small branches. The seeds are brown, broadly boat-shaped and enclosed in tan, reddish tan or chocolate-brown, awned, pubescent (hairy) glumes or chaff. The ripe seeds usually remain in the glumes after threshing, and about 30,000 seeds weigh one pound. Plants of dwarf varieties range from three to seven feet in height, whereas tall (standard) varieties vary between six and 15 feet. A field of tall broomcorn, with its brushy nodding panicles, is an inspiring sight. In the words of a 19th Century New England poet:

"For the tall broomcorn is a warrior born,
In the stern battalions growing,
And his green leaves wave like a banbrave,
When the battle winds are blowing".

Dwarf varieties usually produce one or more tillers or sucker stalks which also bear usable brush. Some dwarf varieties develop constrictions near the base of the peduncle, which provide a ready breaking point when the brush is pulled from the stalk.

History of Broomcorn Culture

Broomcorn culture spread from Italy to other parts of Europe, chiefly France and countries of the Danube basin. Benjamin Franklin is credited with introduction of it into the United States. Franklin did not mention broomcorn in his Autobiography. According to an incident reputed to have been recorded in his personal diary, he returned from England in 1725 and carried a golden snuff box containing a single seed of broomcorn packed in cotton. It had been removed from a whisk broom while he was the guest of Lady Burkhorst. Franklin was in Europe from 1724 to 1726, 1757 to 1762, and 1764 to about 1774. Another story told by Charles Thompson, Secretary of the Continental Congress, places the whisk broom in the possession of a Philadelphia lady. In either case, Franklin is credited with planting the seed that founded the American broom industry.

Thomas Jefferson noted that broomcorn was grown in Virginia as early as 1781. Samuel Hopkins, Hadley, Mass., grew broomcorn in 1778, and Rev. Enoch Hale, Westhampton, Mass., grew it in 1785.

At first, broomcorn was merely a curiosity or a garden crop for making homemade brooms. But in 1797 Levi Dickinson, an eccentric bachelor, grew a half-acre of the crop near Hadley, Mass., and made 20 to 30 brooms which he sold. The next year he grew an acre of broomcorn and made nearly 200 brooms. Others took up broomcorn culture by 1800, and, in 1810, 70,000 brooms were made in the vicinity of Hadley. About 1,000 acres of broomcorn was grown there annually by 1825. Some 770,000 brooms and 76,000 brushes were made in 41 factories in the Hadley section in 1850. The crop was grown in Virginia,

FIG. 2. Cutting the brush from tabled broomcorn.

Massachusetts, Connecticut, New York, Pennsylvania, New Jersey and other States before 1834. Broomcorn culture moved westward to the Mohawk Valley of New York early in the 19th Century. The Shakers, a communistic, celibate, devout, religious sect, took up broomcorn culture and broom-making around Watervliet, Schenectady County, New York, at least by 1834 and probably earlier. The broom industry had become important there before 1845. Broomcorn was grown in 24 counties in New York in 1855. Schenectady, New York, became the chief broom manufacturing center by 1868. Later, factories were established at nearby Amsterdam, where some have remained up to the present time. For many years of the twentieth century, Amsterdam led the country in broom making.

The Shakers were active in spreading broomcorn culture and in making brooms in all of their colonies. They arrived from England in 1774 and founded their first colony at Niskayuna (later Watervliet), New York. In addition to several additional colonies in that State, they established others in Maine, New Hampshire, Massachusetts, Ohio and Kentucky. The Shakers enlarged their membership by accepting converts and adopting orphans, but eventually their numbers declined because both men and women of the sect were faithful to their vows of celibacy.

The Westward March of Broomcorn

Broomcorn continued its westward march from the early 19th Century until about 1930. Its culture passed from the Connecticut Valley by 1880 and from the Mohawk Valley early in the 20th Century. The crop was well established in the Scioto Valley of Ohio by 1844 and in the Miami Valley by 1848. It was then being grown extensively in Virginia and Tennessee. It reached Missouri, Illinois and Wisconsin by 1848. It was grown near Platteville, Illinois, by 1855, near Kankakee, Ill., by 1857, and 800 acres were raised near Rockford, in the northern part of the State, in 1859. A communistic colony of Swedish immigrants grew broomcorn extensively and operated a large broom factory at Bishop Hill, Illinois, before 1860.

Col. John Cofer of Arcola, in east-central Illinois, obtained some broomcorn seed from Tennessee and began growing the crop in 1861. Two neighbors, J. K. Breedon and his brother, also grew the crop the following year. Within a few years Illinois was the leading broomcorn State. The leading producing area was in east-central Illinois, around Mattoon, Charleston, Arcola and Tuscola. That section proved to be so well suited to broomcorn that it still is an important producing center. The nation's top yields and quality usually come from the rich black prairie soils of that vicinity. It is the only humid area in which broomcorn did not succumb to the westward movement.

In 1860 broomcorn even jumped all the way to California, where five acres was grown that year. California broomcorn production increased somewhat thereafter, but it usually has been a minor crop in the State except in 1935 when 3,000 acres were grown.

A Swedish emigrant, Frank G. Hawkinson, moved from Illinois to Marquette, McPherson County, Kansas, in 1869, taking broomcorn seed with him. He and his brothers grew 80 acres of broomcorn on freshly-broken sod in 1870. The first load of brush was hauled 33 miles by ox team to the railroad at Salina, a two-day trip. Hawkinson's neighbors soon began to grow broomcorn, and McPherson County produced 1,156 acres in 1874 and nearly 15,000 acres in 1882.

By 1879, Kansas ranked next to Illinois among the leading States in broomcorn production. Missouri ranked third that year. Broomcorn soon advanced

FIG. 3 (*Upper*). The bunches of cut brush lying on alternate tables are laid on a trailer drawn across the field astride an empty table.

FIG. 4 (*Lower*). The cut green brush slides off the rear of a dump trailer.

across Kansas, and production in McPherson County eventually ceased. After 1910 the crop was largely restricted to a few southwestern counties where it still remains in cultivation on a considerable area.

Broomcorn also had spread from Illinois to Iowa by 1861 and thence to Nebraska before 1875. Nebraska growers liked broomcorn because it resisted grasshopper ravages. Nebraska ranked third in broomcorn production in 1889. The crop at that time was well distributed across the southern half of the State, but it practically went out of cultivation in Nebraska 40 years ago.

After the Sooners "made the run" into Oklahoma in 1889, many took up broomcorn culture. Ten years later Oklahoma ranked third in broomcorn production, and since 1909 has led all other States nearly every year.

Early broomcorn culture in Oklahoma was mostly in the northern and western counties. The most important center was established later in the rich Washita Valley near Lindsay. Robert Watkins and his son-in-law, Fred Tinch, broomcorn growers of Humboldt, Illinois, moved to Lindsay in 1905. The next spring they grew 140 acres of broomcorn, planting Illinois seed. A neighbor grew an additional 15 acres. Other early Lindsay growers from Illinois were Scott Moore and W. K. Donnell. Before long, broomcorn was a major crop in the district, and within ten years Lindsay was the biggest primary broomcorn market in the nation. More than 800 carloads of broomcorn valued at over two million dollars were shipped from Lindsay in 1919. It is still an important broomcorn center.

An appreciable production of broomcorn was under way in Texas, Colorado and California by 1889, and in New Mexico by 1909. Some broomcorn was grown in New Mexico before 1890. By 1909, production had largely ceased in Iowa and Nebraska and the only important commercial production in the eastern half of the United States was in Illinois, Missouri and Tennessee.

Commercial broomcorn production was instigated in Bee and Goliad counties in South Texas by the American Warehouse Company about 1911. The Beeville locality and several outlying sections continue to produce most of the Texas broomcorn crop.

Colorado and New Mexico were the last frontiers of commercial broomcorn culture. Production in both States rose rapidly between 1909 and 1929 as new lands came into cultivation. The Great Plains area gradually becomes drier with the westward rise toward the Rocky Mountains. Dryland farming in the Great Plains sections of southeastern Colorado and eastern New Mexico stops about 50 miles or less from the eastern borders of these States because the rainfall drops too low for successful production of any non-irrigated crop. Consequently the westward march of broomcorn culture was brought to a halt when the last outpost of arable lands was put under the plow about 1930.

Baca County, in the southeast corner of Colorado, was first settled about 1887, at which time the writer's father-in-law filed on a claim, which he soon relinquished, some 50 miles from the nearest railroad. Farming there was a struggle for many years, but the few more resourceful settlers who remained gradually evolved methods for producing crops under the limited rainfall. Broomcorn was their best cash crop. A heavy expansion of crop production there followed World War I. For many years broomcorn was hauled mostly to shipping points in Kansas, but a branch railroad reached Springfield, the county seat of Baca County in 1926. A heavy tonnage of broomcorn awaited rail shipment. Within three years Baca County was the leading county in the world in broom-

corn production, and has held first place since then except in a few drought years.

During most of the past 25 years about 99 percent of the national broomcorn crop has been grown in six States—Oklahoma, Colorado, New Mexico, Kansas, Texas and Illinois. Production is restricted to one or a few favored sections in each State. Production in other States is mostly for local broom factories, and the acreage is small in each case. When prices are high, however, farmers seeking a bonanza occasionally attempt commercial production in many parts of the United States outside the usual areas. Such efforts usually are short-lived because of difficulties from inexperienced help, inadequate facilities for obtaining a good quality product, and a shortage of competitive buyers. Broomcorn can be grown in every State in the Union, although the quality of the brush from wet or cold climates or poor soils may not be wholly satisfactory.

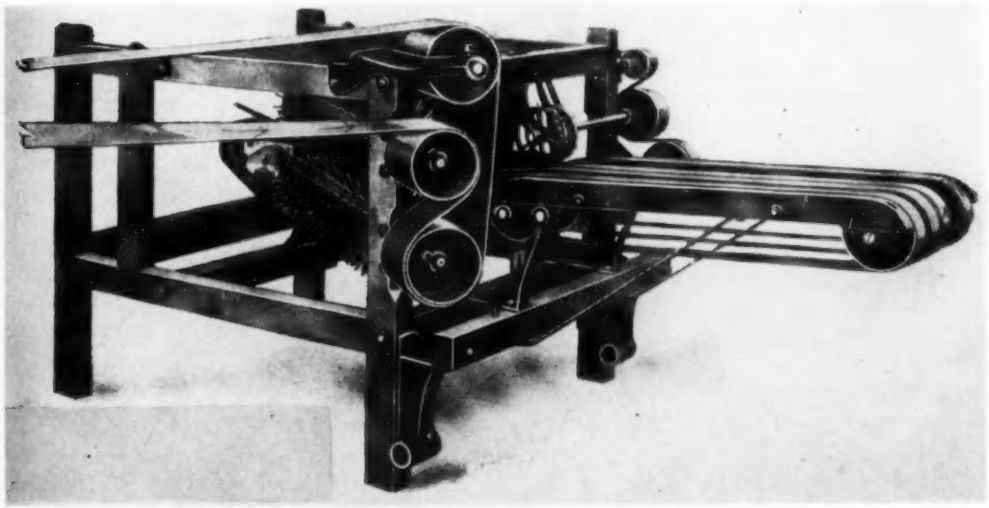

FIG. 5. Broomcorn scraper or thresher with sides removed to show the mechanism.

How Broomcorn Is Grown

The methods of growing broomcorn up to harvest time are essentially the same as for growing corn or grain sorghum in any particular locality. It is planted at about corn planting time and up to one month later. The seed is planted about one inch deep in rows from three to three and one-half feet apart, using from two and one-half to four pounds or more of seed per acre. A corn planter or lister furrow planter, in either case with special broomcorn seed plates, is used. Desired stands of plants are two and one-half to four inches apart in the row in the humid districts of east-central Illinois and central Oklahoma, and from six to nine inches apart in the semi-arid districts of Colorado, New Mexico, Kansas, and western Oklahoma and Texas. About two-thirds of the seeds sown develop into plants under favorable conditions. Intertillage for weed control is the same as for other row crops in a particular district. Two or three cultivations are common in semi-arid sections, and four or five cultivations in sub-humid areas. Two-row or four-row planters and cultivators are popular in humid areas and three-row to six-row lister-type machines are customary on dryland farms.

Broomcorn growing is now largely confined either to sections of economical

production or where a high-quality of brush is obtained. These sections have adequate marketing facilities and also threshing and baling equipment that operates on a custom basis. There seems to be little need at present for bringing in any more new producing areas.

Broomcorn is gathered shortly after pollination is completed, when the seeds are in the milk. Later harvesting results in reddened harsh brush. The harvesting and handling of the brush are unique operations, involving from 80 to 150 hours of man labor for each ton of brush. Broomcorn, like tobacco, has not yet yielded to mechanical harvesting because inspired inventors have never evolved a satisfactory machine. Each brushy panicle, like each tobacco leaf, must be cut or pulled from the stalk individually while rejecting those that are unmarketable. In subsequent operations of bunching, hauling, curing, seeding and baling, the brush is kept straight and untangled, and consequently must be handled in small bunches or armfuls. The peduncle or handle supporting the brush is cut six to ten inches below the joint where the fibers arise, and must be pulled free from its enveloping sheath at the same time. Considerable skill is required to coordinate this cutting and pulling (Fig. 2).

Dwarf varieties usually are pulled or "jerked" from the standing stalk without cutting. Tall or standard broom often is cut from the standing stalk in semi-arid sections when the plants are not more than seven feet high. In humid areas and often elsewhere the stalks are so tall that they either must be broken or "tabled" before the brush is cut. In tabling, a man walks backward while breaking over the stalks of two rows at a height of two and one-half to three feet. The upper sections of the stalks from the two rows are intertwined and intercrossed diagonally and laid horizontally to form a "table" at a height convenient for cutting. The tops project beyond the rows at each side of the table.

For each ton of cured brush, a man walks backwards from two and one-half to six miles in tabling. When cutting, a man walks between two tables and cuts the brush on each side. During cutting, small bunches of brush are laid on alternate tables (Fig. 3) and it is hauled to the seeder (scraper) within 24 hours or less. Brush pulled or cut from short standing stalks is placed in bunches between the stalks and may be left there to dry for several days if it is to be cured in a rick. Otherwise it is hauled promptly and dumped on the ground near the seeder (Fig. 4).

Green brush for shed curing is seeded (threshed) with a power seeder set near the curing shed. It is picked up from the dump piles in armfuls, carried to the long table of the scraper where it is laid out straight, evened at the butt ends ("butted up"), partly culled and then fed into the thresher. The brush is clasped between two toothed endless chains of the scraper or seeder while the seed is knocked from the tip end of the brush by the whirling spikes of twin threshing cylinders (Fig. 5). Armfuls of the seeded brush are then picked up and carried to the slat-sided curing shed. Seeding before curing provides better brush because fewer fine branches are broken off when the brush is damp.

In the curing shed the brush is spread out about four inches thick on paired slats in tiers six inches apart vertically (Fig. 6). It cures ready for baling in from ten days to two weeks. In the drier western districts much of the brush is cured in outdoor ricks about five feet wide at the base, with sloping sides, built four to five feet high and any convenient length. In ricking, as in hauling, the brush is laid straight in double tiers, with the seed end of the brush outward. The rick, and sometimes the load, is topped off with a single tier of brush.

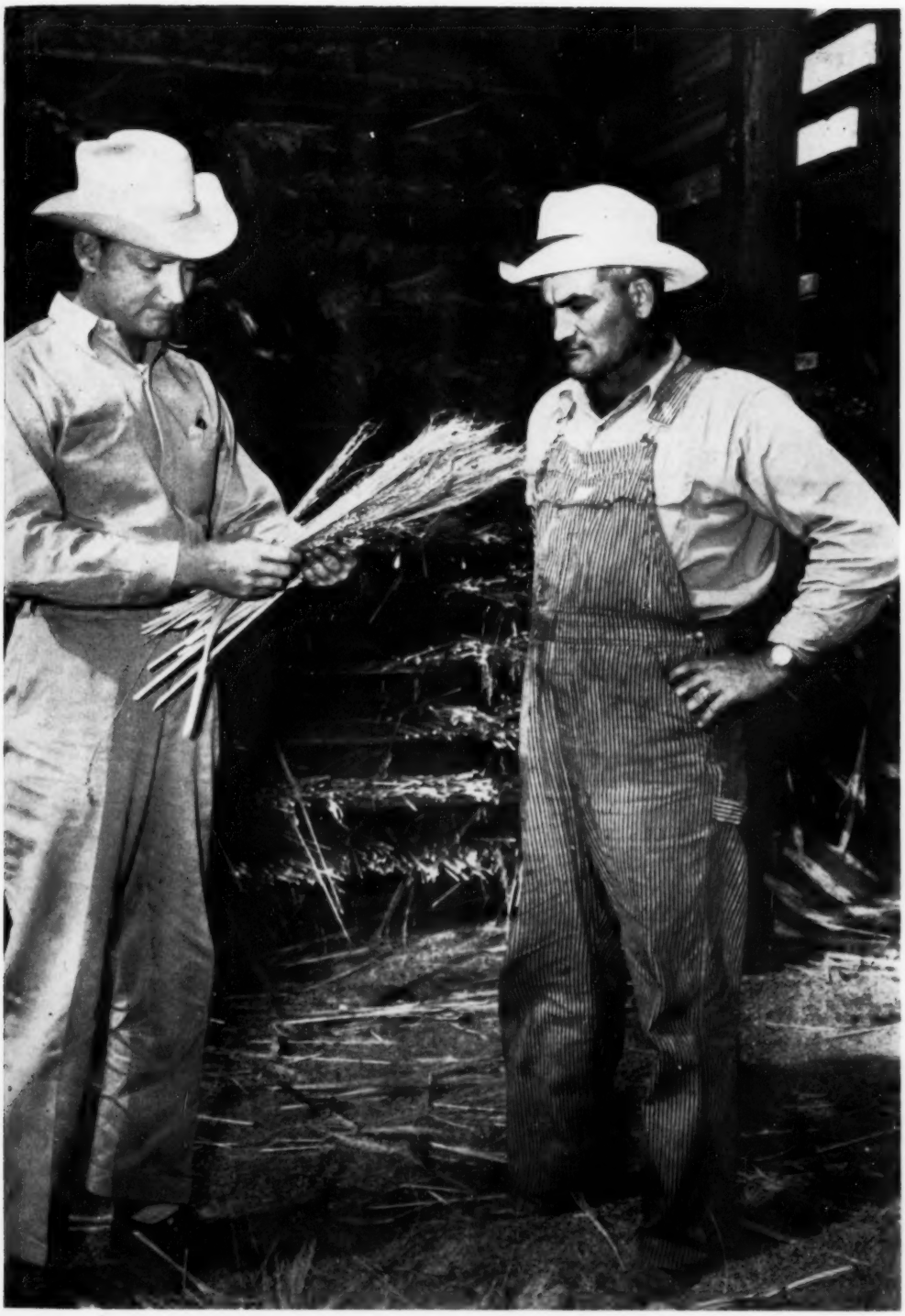

FIG. 6. Examining brush taken from the shelves of the curing shed in the background.

Rick-cured brush usually is seeded after curing in order to save labor, and then is carried directly from the seeder to the baler (Fig. 7).

The brush is laid in the baler chamber in two partly overlapping tiers with the butts outward. The chamber is then clamped shut and pressure applied from the bottom to compress the brush. Motor or horse power operates the compressor. The compressed bale is tied with five No. 11 wires and then released from the baler. The average bale weighs from 330 to 340 pounds (Fig. 8). Twelve to 13 tons fill an average railway box car.

Early American broomcorn growers stripped the seed from the brush by hand. A curry comb was a useful scraper. Later the brush was scraped between a pair of hand operated jaws of a flax "break" or similar device. The next type of scraper was a "hetchel" or hackle, consisting of a row of upright teeth through which the brush was drawn. Scrapers consisting of toothed cylinders turned by horsepower were in use by 1847. Gray's Broomcorn Scraper, a machine with paired cylinders running in opposite directions, as in present-day scrapers, was available by 1873. With this machine the brush was held in the hands during the threshing operation. The feeder chain for holding the brush during the scraping was devised a number of years later and was in general use in Illinois in 1893. The scraping of a ton of brush by hand took a man about seven days. With a modern power scraper, the efficiency of man labor is increased about six-fold.

Early growers sometimes baled broomcorn brush in a hay press or tobacco baler, but special broomcorn balers were manufactured before 1891. Small lots of brush sometimes are still marketed locally in bundles tied with rope or twine.

The harvesting of brush requires from ten to 24 hours of man labor an acre or 50 to 90 hours a ton. A seeding crew consists of ten to 30 men. With shed-cured brush the crew tables and cuts about three-quarters of the day and then seed and shed the day's cutting. A typical baling crew consists of eight to ten men. Thus many seasonal laborers are required in a heavy-producing broomcorn section. Formerly itinerant broomcorn hands, often called "johnnies", stayed on the farm where they slept in barns, sheds or corncribs. Such sleeping quarters were not always free from fleas or barnyard odors. Now the men lodge in town, and groups ride to the farms in cars.

The glumes or chaff of the broomcorn panicle bear numerous hairs. These hairs become detached in handling, particularly during threshing. The hairs are very irritating to the eyes and to a perspiring skin, producing what is called "broomcorn itch". Scratching of an itching skin sometimes induces skin infections. After several itching weeks, it is customary for both growers and field hands to swear "never again" (they usually use stronger language). But, since time heals all itches, including the seven-year variety, it is more than likely that many of the men are back in the broomcorn field the next year. The writer once encountered a crew in southwestern Kansas threshing smutty broomcorn, where the air was filled not only with itching hairs but also with a dense cloud of black smut spores. After ten minutes of close observation, some of the crew members were found to be negroes. All of the worker's faces were equally black, and the writer's features by then were tattle-tale grey.

The Making of Brooms

Brooms are made in 200 or more commercial factories distributed over the United States, mostly in or near large centers of population. They are so located because it is economical to buy

FIG. 7 (*Upper*). Carrying brush from the scraper to the baler.

FIG. 8 (*Lower*). Buyers of the street market inspecting bales of broomcorn while the growers ponder over the price offered.

and ship the brush and handles from distant points, while marketing the completed brooms in the vicinity. Little broomcorn is now grown in populous areas. Strangely the largest broom factory in the United States is located in the village of Deshler, Nebraska, in a rural community in the southern part of that State. Many of the men and women workers come from surrounding farms, since the number of employees in this one factory exceeds the population of the town. The factory was established many years ago when broomcorn was grown in the vicinity. Now the brush must be shipped from producing areas nearly 500 miles away, while many of the brooms move even greater distances. Good management and "good will" make this a successful enterprise.

There are hundreds of small so-called "buckeye" broom shops distributed over the country in cities, towns, villages and on farms (Fig. 9). Many of these are part-time one-man shops, although family or hired labor may be employed in busy periods. The "buckeye" term originated when small shops were numerous in Ohio.

Bales of broomcorn are opened at the factory and the brush is sorted. Long coarse brush is used for making warehouse brooms. Short brush is used for the insides of household broms. Short fibers and the trimmed tips of long fibers are used in whisk brooms. Formerly a dwarf variety with short fibers was grown especially for making whisk brooms. Medium-long, fine, smooth fibers, which form the outside or "hurl" of the household broom usually are the most valuable. This fiber, the cover layer, and some of that used for the insides of the broom, is first cut from the handle or peduncle of the brush after bleaching and dyeing. The severed fibers are then sorted or sized mechanically for both length and diameter, and then tied in bundles. Most brush is dyed in a vat containing a solution of malachite green (basic green crystals). This restores the green color to bleached and slightly discolored brush. Bundles of brush from the dye vat are drained and then transported to the bleaching chamber. There the brush is exposed to sulfur dioxide fumes from sulfur burned in pots placed on the floor. Bleaching lightens the shade of the dyed fiber somewhat but chiefly destroys dark discoloration caused by exposure to weather. Red stains, which frequently occur on the brush, result from pigment absorbed from injured leaf sheaths, especially following aphis infestation, wet weather or delayed harvest. Neither dyeing nor bleaching eliminates the stain to an appreciable extent. Some manufacturers dye reddened brush a bright red, orange, blue or purple, and then market the brooms as novelty products. Broomcorn breeders are now trying to develop a good quality broomcorn from strains that do not develop red stain. These were produced from crosses with certain varieties of sorghum that are free from red staining.

The brush is still damp when it is carried to the broom maker. The fibers must be soft and pliable when worked into a broom. Piles of sorted brush are placed where the broom maker can reach them readily.

The first step in broom making is to clamp the wooden handle into the chuck of the winder. Then one end of a spool of wire is tacked or nailed to the handle near the bottom end. Spring pulleys keep the wire at a suitable tension. The next step is to place a handful of short brush next to the wire at the proper point on the handle and start the winder. As the handle revolves in the winder, the taut wire binds the brush close to the handle, care being taken by the operator to spread the brush and feed it uniformly under the wire all around the broom handle (Fig. 9). After sufficient brush for the "insides" has been applied, the

FIG. 9. Making brooms on a home-made broom winder with a stitching clamp attached.

head of the broom is trimmed with a knife while the winder turns slowly. Usually the fibers used for the insides has not been cut from the peduncle or brush handle, and it is these stalk ends that, by trimming, are tapered down to the broom handle. Short and coarse fiber may be used for the insides.

The next step is to build the shoulders of the broom. The shoulders are formed with two bunches of fiber wound on opposite sides of the broom. Usually these two bunches are attached with the tip ends of the fibers pointed upward and then are bent double to form rounded shoulders, and held down with a loop.

FIG. 10. A broom after winding (left) and after sewing (right). Mechanical stitcher in background.

Then a layer of " cover " fiber is applied around the outside of the broom. This is followed by a finishing course of " hurl " fiber, and the wire is nailed to the handle and cut free from the reel. The head of the broom is trimmed to final shape and covered with closely wound wire or a metal case and often with a ring of velvet (Fig. 10). Then any remaining seeds on the brush are threshed off. Then the broom is clamped in a shaping mold and stitched with four or five seams. Trimming the bottom end to a gentle curve or sometimes square (Fig. 11) and attaching a label to the handle completes the broom. Brooms of various types weigh from 18 to 50 pounds per dozen, typical household brooms about two pounds each.

The chief innovation in broom design during the history of the industry was the spreading of the brush and the addition of two shoulders, giving it the flat shape of the modern efficient broom. This was a creation of the Shakers at Watervliet, New York. The hurl broom, with long fine fibers (hurl) placed around the outside of the broom, followed a few years later, by 1842. The first broom winders were operated by a hand crank, but foot treadle winders came into use before 1870. A broom clipper was constructed about 1868. The first power sewing machine was invented in 1875, and the hurl cutter, sizing machines and power winder soon followed. Twine was used for winding most brooms until about 1870 when it was replaced by wire. Some wire had been used at least 25 years earlier, but it often proved to be too brittle, until better steel wire was available.

Early broomcorn brooms were round, like a typical " witches broom ", and were wound and sown with twine by hand, much as the twig and grass brooms had been made in the household for centuries. With the simple hand tools available in 1832, one man could make about 10,000 such brooms in a year, using five tons of brush in the process. With a modern machine a man can wind a broom in about three minutes (Fig. 12).

A rope frequently was suspended from a rafter with a loop for a stirrup at the bottom end. Pressure with the foot in the loop after a turn of the rope around a bundle of brush compressed the fibers. This held the brush tight while the bundle was rotated for winding, and also during the sewing. A handle was sharpened at one end, driven down into the center of the broom, and then nailed fast.

Broomcorn Varieties

The chief varieties of broomcorn grown are Black Spanish (Black Jap), White Italian (Evergreen), Scarborough Dwarf, Evergreen Dwarf and Fulltip (Miller's No. 8). The latter three are dwarf varieties grown mostly in Oklahoma, New Mexico, Texas and Kansas. Black Spanish is the chief variety in the short-season area of Colorado and also in the Lindsay district of Oklahoma. This variety has been grown in the United States since 1887 and probably since 1842. Illinois grows mostly White Italian and other strains of the Evergreen, standard types, and some Black Spanish. The Evergreen Dwarf variety has been grown in the United States at least since 1873. Various strains of the Evergreen Standard variety have been introduced from Europe from time to time. One of these, White Italian, was introduced from Austria about 1911 by C. L. Howard and Jake Wasserman, of Amsterdam, New York. George L. Pfeiffer, of Arcola, Ill., crossed White Italian with Black Spanish, and from this cross selected the Illinois Favorite variety, which he introduced in 1922. A few years later, H. Z. O'Hair, of Bushton, Ill., introduced Black Spanish Dwarf which he had produced from a cross between the Black Spanish Standard variety and Scarborough Dwarf. The Scar-

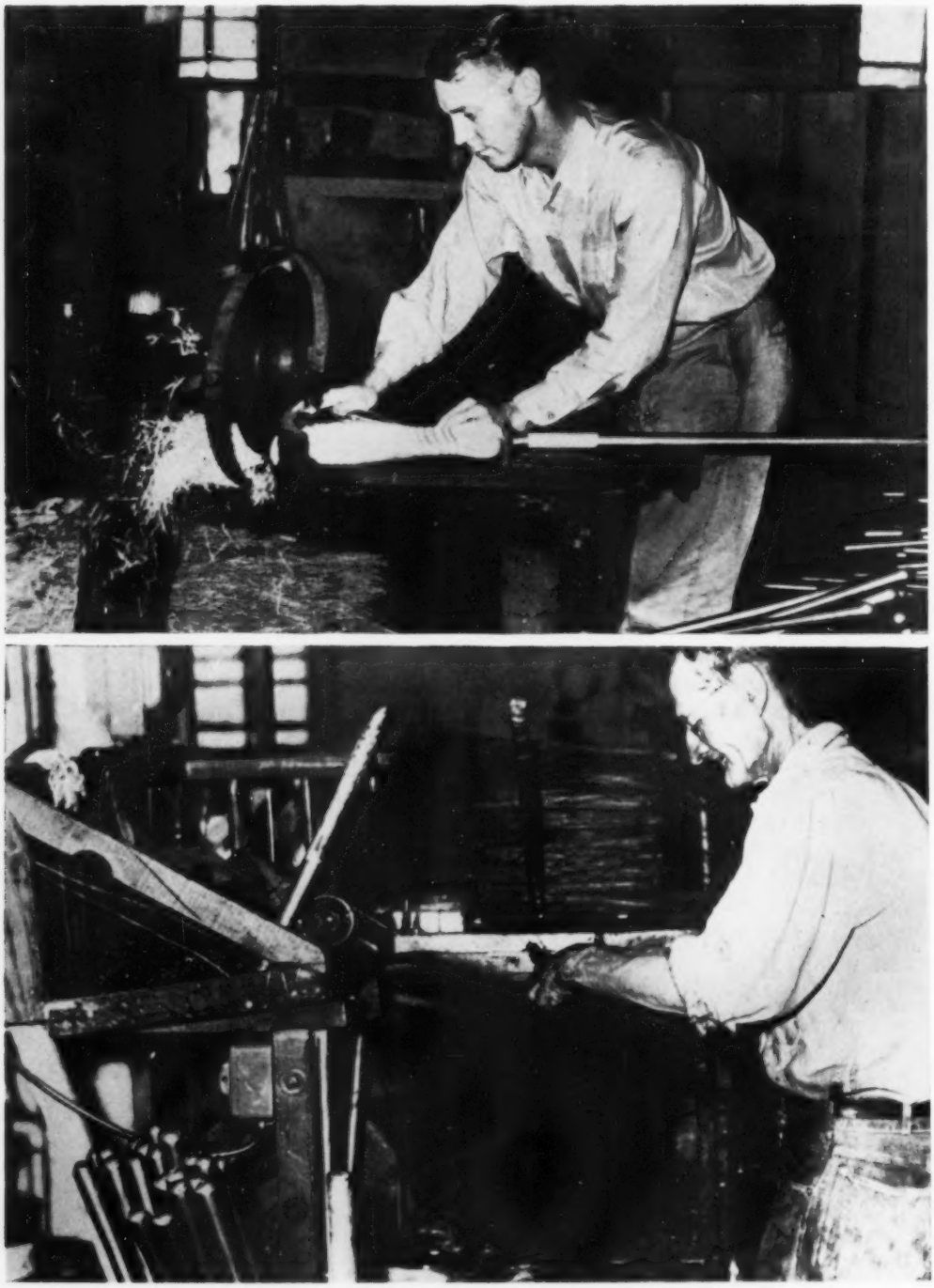

FIG. 11 (*Upper*). Clipping the end to a rounded form completes the broom.

FIG. 12 (*Lower*). Making brooms on a power winder with piles of sized brush within easy reach. This worker winds about 12 dozen brooms in a day.

borough Dwarf originated from a single plant selection made on a farm in Texas County, Oklahoma, in 1910. It later became badly mixed but was reselected by John B. Sieglinger.

Broomcorn breeders in Oklahoma, Illinois, New Mexico and other States have sought to develop a better quality of brush. Many plants fail to bear top-quality brush except under the most favorable conditions. Too much space in the row may cause a plant to produce fiber that is too long and coarse, with a thick center stem and often crooked. Crowding of plants in the row and deficient soil moisture cause stunted brush or even unusable "tree top" panicles. Unfavorable weather, causing irregular growth, may result in kinky or curled fibers. Wet weather and aphid attacks redden the brush. Such environmental abnormalities are difficult to overcome by breeding because they occur in some plants of even the purest inbred strains. Nevertheless some improvement has been achieved, particularly in breeding good hurl-type varieties such as Fulltip and Scarborough Dwarf. Varieties free from red strain bred from a cross made by the writer, were released to growers in Illinois early in 1953. Promising strains now under test are nearly free from coarse center stems. Center stems are useless in broom making. The Fulltip panicle has such a long handle (peduncle) that the fibers are largely exserted from the boot and thus less subject to red stain. In fact, for this reason Fulltip is the only dwarf variety adapted to humid areas.

The "Dean" of broomcorn breeding and broomcorn research, a long-time asociate of the writer, is John B. Sieglinger, of the U. S. Department of Agriculture, now stationed at Stillwater, Oklahoma. He bred Fulltip broomcorn and selected a high-quality strain of the Scarborough variety now widely grown, both in cooperation with C. C. Miller who introduced these improved types. He also pioneered in developing dwarf grain sorghums for combine harvesting. Raised on a farm in western Oklahoma, John Sieglinger worked in broomcorn fields during his boyhood. After completing his undergraduate education at Oklahoma Agricultural and Mechanical College, followed by a Master's degree at Kansas State College in 1915, he started testing and breeding broomcorn and sorghum at the Southern Great Plains Field Station, Woodward, Oklahoma. He is still carrying on broomcorn improvement without any visible diminution in energy or enthusiasm. He is now an honored man in Southern agriculture. His practical accomplishments and his discoveries in crop science doubtless have contributed more to national progress than some ten million words of typical rural uplift propaganda.

The Relation of Plants to Public Health

In addition to furnishing clothing, food and shelter—the basic necessities of life—plants, in their utilization by man, have also furnished problems of public health in their production of alcohol, narcotics, allergies, poisons and specific human diseases.

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Introduction

The three great necessities of life—food, clothing, shelter—and a host of other useful products are supplied in great part by plants. Plants are important also to man's health in many other ways. Bacteria, viruses, rickettsiae and fungi cause the majority of human diseases. Nitrogen-fixing bacteria convert free nitrogen of the soil into a form usable by plants, and thus promote the production of high protein foods. The aesthetic value of the higher plants and the amelioration of meteorologic conditions have no small influence on man's health and enjoyment of life. Man is a park animal. When he emigrates into a forested area he cuts down trees, and when he migrates into a grassland area he plants them. Apparently man has learned that the park-like aspect of the landscape best suits his needs from the standpoint of health and safety.

Of tremendous importance to man's health is the control of erosion and floods, which can be accomplished only by proper cover of forest, scrub or grassland. One of the outstanding examples of the role of plants in the control of erosion is the formation of the so-called "Ducktown Desert" at Copperhill, Tennessee. Near the turn of the century (1902) a new smelter for the processing of copper ore was built at Copperhill. In the smelting process sufficient sulfur dioxide was released to destroy nearly all the vegetation in an area almost seven miles in diameter. As a result of the destruction of the plants, the soil eroded away by the tons; all of the topsoil and much of the parent material were removed, and huge gullies up to 30 feet deep were formed. At present this area is still a desert; at least one reservoir in the Tennessee Valley has been largely filled by this sediment, and the flood hazard has been increased considerably.

The multiple effects of plants on the health of man can be best illustrated by the water hyacinth. "The water hyacinth often becomes so abundant in natural streams that it impedes run-off and increases backwater and flood conditions in many areas . . . . In at least one case water hyacinth blocked a stream carrying sewage with subsequent backing up of this material into a populated area . . . . The shifting of water hyacinth rafts often prevents the egress of a sportsman from a recreational area . . . . Such an event . . . may result in considerable inconvenience and discomfort, and in rare cases it may result in undue exposure, sickness, or even death. . . . In some cases aviators have mistaken green ribbons of water hyacinth for landing strips, to their own amazement, danger, and financial loss. . . . Last, but not least, should be mentioned the health hazard due to the breeding of mosquitoes" (Penfound and Earle, 1948).

Plant Products

The public health of a people is directly concerned with the quantity and quality of its food. In the United States the quantity of food is not nearly so much of a problem as the kinds and quality of food that we consume. Although we are concerned here primarily with the quality of vegetable foods, it should be pointed out that the quality of our animal products is directly dependent on the quality of the feed they eat. Albrecht (1948) points out that climate controls the soil, that the soil controls the nutritional quality of food, and that the quality of food controls our health. He believes that the west central portion of our country, with high-calcium soils, produces the best food. According to Albrecht, the plants, especially corn and wheat, are higher in proteins, minerals and vitamins. He also states that the animals have better bones and muscles, with less fat, and that the human population has lower tooth decay, better musculature, more energy and greater fecundity.

Consumption of alcoholic beverages has presented important public health and sociological problems. As is well known, alcohol is produced from vegetative parts—fruits and seeds of plants, by several species and varieties of yeasts. This group of plants has been responsible for a tremendous amount of social and political activity, and has even been the cause of two changes in the Constitution of the United States of America. Because of the deleterious effects of alcohol on the human system and the development of so-called "alcoholism", the production and consumption of alcoholic beverages has been of considerable concern to public health authorities throughout the world.

"In all ages and in all countries, human beings have smoked or chewed various substances for pleasure, for some physiological effect, or in connection with their religious ceremonies" (Hill, 1937). The majority of the materials which are chewed or smoked have a stimulating or narcotic effect due to the presence of various alkaloids. Tobacco, betel and cola are the least harmful of these substances. It is a different matter with coca, cannabis and opium which are injurious in small amounts and which, when used in quantity, may cause stupor, convulsions and even death.

The chewing of the leaves of the coca plant is a centuries-old custom among the Indians of South America. "The Indians who use coca can resist physical and mental fatigue and work for long periods without food and drink" (Hill, 1937). This custom soon becomes a habit, however, and leads to physical deterioration and even death. The use of coca, and its derivative cocaine, is subject to very strict regulations in most countries.

Cannabis is a narcotic drug derived from the hemp plant, which has been used as a stimulant for 2,000 years. Hashish, as the preparation is called, is smoked mainly in the Middle East, but has been grown in southeastern United States for the production of marihuana cigarettes. Its use causes a stupefying and hypnotic effect, accompanied by hallucinations, agreeable and often erotic dreams, and a general state of ecstasy. Despite all efforts to stamp out its use in the United States, the production of marihuana cigarettes seems to be increasing.

Opium is a very old narcotic which has spread to all parts of the world. The immediate effects of smoking it are pleasurable, including alluring dreams and visions. Continued use, however, leads to delirium and death. The opium habit is still increasing, particularly in the Orient, where it has taken a toll of millions of lives. When morphine addiction is added to the opium-smoking

habit, it should be evident that "the suppression of the illegitimate use of opium products and allied narcotics is one of the gravest problems of public health today" (Stanford, 1934).

Modern medicine finds itself more and more concerned with personal and social hygiene, the prevention of infectious disease and the conditions of living, and correspondingly less with the actual treatment of disease. In the treatment of disease, more and more of the drugs of plant origin are being replaced by synthetic drugs. As a result, the role of plant drugs has decreased tremendously during the first half of the twentieth century. Despite this fact, over a million pounds each of the following crude drugs were imported in 1935; ephedra, hops, licorice, nux vomica, psyllium, pyrethrum, quinine and senna.

Another group of substances of public health interest are the aromatic products of plants. These aromatic products, including the spices, are used in food and medicines to add flavor and to stimulate the appetite. They are also used to preserve food by retarding bacterial action. "In the small quantities ordinarily used, they impart agreeable flavors and disguise disagreeable ones—a desirable effect in disguising unpleasant medicinal mixtures but less so when hiding incipient putrefaction in sausages or the flavor of mold in tomato products" (Stanford, 1934). With the use of refrigeration, this practice has fallen considerably, but it is still a public health problem in the warmer portions of the Americas where ice is difficult to procure and electricity is unavailable.

In the past, medicinal plants usually were seed plants. At the present time a host of substances, known as "antibiotics", have been isolated from the lowest division of the plant kingdom. Scientists have isolated pyocyanin, tyrothricin and subtilin from the bacteria; they have produced actinomycetin, actinomycin, aureomycin, streptothrycin and streptomycin from the actinomycetes; and they have developed clavacin, gliotoxin and the "wonder drug", penicillin, from the molds. Altogether more than 200 compounds having bacteriostatic and fungistatic properties have been isolated from microorganisms, and there is evidence that many more will be produced. Although only a relatively few have been effective in therapy, "the utilization of the activities of antagonistic microorganisms for the control of human and animal diseases has only begun" (Waksman, 1947).

Allergenic Plants

The twentieth century has been noteworthy in the increase in allergic diseases and the recognition of allergenic plants as a public health problem. Although uncivilized tribes undoubtedly developed allergic manifestations, this disease is one of the dubious privileges of civilized peoples. Urbach and Gottlieb (1946) ascribe this, in part, to "the increasing artificiality of our diet; faulty diet; the hectic tempo, excitement, and tension of city life; central heating and air conditioning; and polluted air". Literally thousands of species of plants have been incriminated in the development of urticaria, hay fever, asthma and other allergic syndromes. Allergic reactions may be initiated through contact, inhalation, ingestion or injection of the sensitizing substance.

Undoubtedly the most allergenic contactant is poison ivy. Any part of the plant, and even the particles carried in smoke from burning plants, may cause severe dermatitis on susceptible persons. The related poison sumac is also a potent allergenic plant. Other contactants causing allergy include seeds (especially castor bean), roots (orris root), woods, fibers (kapok), flowers, pollen and fruits. Of even greater importance than gross plant parts are substances produced industrially from these plant parts which constitute a group of substances almost

peculiar to civilized man. These include dyes, resins, lacquers, plastics, turpentine, rubber, cosmetic bases, ethereal oils and soaps.

Millions of people in the United States alone develop allergies because of inhaled materials. Of the lower groups of plants, the molds are the most important. Mold spores are only three to five microns in diameter and are carried great distances in the wind. Fortunately allergy due to fungi is much worse in moist warm climates, although it may be important during rainy weather in midsummer, even in relatively arid temperate climates. It is probable that more people suffer from inhaled pollen (pollenosis) than from any other plant material. In order to cause hay fever, asthma or other allergic disease, the pollen must be wind-borne and must be toxic to the mucosa of the sensitized individual. In most areas the allergy season is divided into tree, grass and ragweed seasons. Undoubtedly the most potent inhalant allergens are pollens from the ragweed group. It has been estimated that there are over 3,000,000 persons in the United States who suffer from hay fever caused by ragweed (Weinstein and Fletcher, 1948).

Public health problems also arise from inhalant allergies in connection with the processing of plants. In the processing of cotton, patients may become sensitized either to cotton linters or to cottonseed meal. The dust of castor beans may become an allergen to individuals living in the neighborhood of castor oil mills. People around mills processing flax often become sensitized to flaxseed meal and are sensitive thereafter to fresh paint, varnishes, linoleum, oilcloth and other products containing linseed oil. The same is true even for mills producing cereal flours such as barley, corn, oats and wheat.

Our discussion on allergy would hardly be complete without some comment on the methods of controlling allergenic plants. Control of any plant species may include mechanical, chemical or biological methods. In general, mechanical procedures, such as pulling and mowing, are too time-consuming and too expensive. Biological methods, such as the importation of parasites or predators, demand highly trained personnel and may endanger economic plants.

Great progress has been made during the last decade in chemical methods of plant control. In 1938, ammonium sulfamate, sodium chlorate and sodium arsenite sprays were the herbicides of choice, although fuel oils and phenolic compounds were utilized to some extent. By the close of World War II, 2,4-dichlorophenoxyacetic acid (2,4-D) had been discovered. Formulations of 2,4-D and related compounds are effective in concentrations as low as one pound per acre, are non-toxic to animals and may be applied either as dust or as a spray. They are very effective on both the giant ragweed and poison ivy, probably our two most important allergenic plants.

Poisonous Plants

A very important public health problem is food poisoning. Foods may be either inherently poisonous or contaminated with poisonous substances or with certain bacteria. Prevention of food poisoning is dependent upon proper methods of food storage, good sanitary conditions and inspection of food handlers.

Mushroom poisoning has been known for thousands of years. Mushrooms may be classified broadly into gastro-intestinal, nerve-affecting and blood-dissolving types. Treatment, obviously, depends upon the type of poisonous mushroom ingested. The public health problem is primarily one of teaching field personnel either to recognize poisonous mushrooms or to refrain from eating any mushrooms (Pammel, 1911).

The death of livestock by phytoplankton (water bloom) poisoning was reported as early as 1878. paralytic shell-

fish poisoning of man has been known for over 100 years. " The peak of mussel toxicity is associated with ' blooms ' of dinoflagellates which are commonly referred to as ' red tides ' " (Olson, 1949). Widespread outbreaks of gastroenteritis along the Ohio and Potomac rivers were reported during the drought years of 1930 and 1931. Since the bacteriological quality of the treated water was acceptable, the gastrointestinal upsets were ascribed, at least in part, to phytoplankton toxicity. In this connection the United States Public Health Service has awarded grants for an expanded program on phytoplankton poisoning.

Phytoplankton are also important to man's health by rendering water supplies unattractive because of bad taste and odor. Although flowering aquatic plants have often been accused of rendering potable water supplies unpalatable, it is probable that they contribute only strongly vegetable odors, and then only upon decomposition. It is quite otherwise with diatoms which cause aromatic odors; with the blue-green algae which contribute grassy odors; and with certain diatoms and some green algae which impart fishy odors to water supplies. Protozoa, especially *Synura,* are important contributors of fishy odors. Control is usually effected by the use of copper sulfate or by chlorination, either singly or in combination. Unbelievably small amounts of copper sulfate (0.1 to 10.0 parts per million) are effective for eradication of the phytoplankton and zooplankton, although bacteria and other planktonic organisms may appear after the original microorganisms are destroyed (Whipple, 1927).

Human Diseases

In the United States pellagra has been prevalent in the South, but with addition of foods containing vitamin G (such as yeast, leafy vegetables, soya beans, fresh lean meats and milk) this disease has almost disappeared. Scurvy is a food-deficiency disease caused by the absence of the vitamin, ascorbic acid. With the inclusion of fresh vegetables, fresh fruit, especially oranges and lemons in the diet, this disease is rarely encountered today. In the past, beriberi has been common in the tropics where polished rice is an important dietary staple and in the far north where the winter dietary may be restricted largely to white flour and other non-vitamin-bearing foods. Treatment is usually effected by a high-vitamin plant diet, supplemented by rich sources of the vitamin B complex, such as Brewer's yeast and extract of rice polishings.

In the United States ascariasis is primarily a dooryard and household infection. In the Orient, on the other hand, it is associated with the use of " night soil " in normal agricultural practice, with the concomitant infection of leafy and other fresh vegetables. The public health problem involves avoidance or treatment of contaminated areas, refraining from consumption of fresh plant products, and proper cooking of vegetables and fruits. The sheep liver fluke occasionally causes symptoms in man. The infective, or metacercarial, stage is readily acquired by man in endemic areas through ingestion of aquatic vegetation, such as water cress. In many parts of the world, plants are related to hookworm infection and hookworm disease. In the tropics, coffee, banana and sugar cane plantations are ideal for the growth and development of the larvae. In other parts of the world, such as China, dissemination is furthered by the utilization of untreated night soil as a fertilizer. It is not surprising, therefore, that hookworm infection often parallels the intensity of agriculture in such regions.

Regarding the relation of plants to malaria control, Hinman (1938) observed that " *Anopheles quadrimaculatus* breeds

almost exclusively in aquatic and semi-aquatic vegetation or in flotage (fine drift composed mostly of vegetable debris) " and that " if these two sources of protection to the larvae could be removed or controlled, our problems of malaria control in the Southeastern States would be practically solved ". In the control of woody plants, ground level cutting of trees (low-stumping), poisoning of stumps and spraying of coppice with herbicides (especially 2,4-D) have proven effective measures. With herbaceous plants current methods include complete removal, recurrent cutting and application of 2,4-D. The cheapest and most efficient control of shoreline plants has been by water level manipulation. This is based on the fact that a rise in water level during the growing season above the summer pool level destroys terrestrial plants and that a drop in water level of two or more feet below the summer pool level destroys many or all of the aquatic plants. The result is a shoreline relatively free of plants of importance in mosquito control.

Summary

Plants promote the health of human beings in many ways. In nature, they are utilized to ameliorate meteorological conditions, prevent erosion and floods, and to embellish recreational areas. In addition to the three great necessities of life—food, clothing, and shelter—plants provide a host of other healthful products, such as vitamins and drugs. Vitamins are noteworthy in preventing deficiency diseases, for example, pellagra, scurvy and beriberi. Plant drugs, especially the relatively recent antibiotics, are among the most important therapeutic agents. Other plant products, for instance, alcoholic beverages, fumitories and masticatories, are widely used but are of doubtful health value.

Plants may also be unfavorable to man's health, especially the disease-producing microorganisms. Poisoning by bacteria and mushrooms has been known for many years. Phytoplankton often produce bad taste and odor in drinking water and have been indicated recently in cases of poisoning in man. Entire plants, plant parts (*e.g.*, woods, fibers, pollen, seeds) and especially plant products (*e.g.*, dyes, resins, lacquers, plastics, oils, soaps) may cause allergic diseases. Other human diseases, such as those caused by ascarid worms, sheep liver flukes and hook worms, are often transmitted by plant parts. In malaria, aquatic plants promote the disease by favoring the development of anopheline mosquitoes, the vectors of the malaria parasite.

Literature Cited

Albrecht, W. A. Climate, soil and health. Oral Surg., Oral Med. & Oral Path. **1**: 199–214. 1948.

Hill, A. F. Economic botany. 1937.

Hinman, E. H. Biological effects of fluctuation of water level on anopheline breeding. Am. Jour. Trop. Med. **18**: 483–495. 1938.

Olson, T. A. History of toxic plankton and associated phenomena. Sewage Works Eng. **20**: 71–72. 1949.

Pammel, L. H. Manual of poisonous plants. 1911.

Penfound, Wm. T., and T. T. Earle. The biology of the water hyacinth. Ecol. Monogr. **18**: 447–472. 1948.

Stanford, E. E. Economic plants. 1934.

Urbach, E., and P. M. Gottlieb. Allergy. 1946.

Waksman, S. A. Microbial antagonisms and antibiotic substances. 1947.

Weinstein, I., and A. H. Fletcher. Essentials for the control of ragweed. Am. Jour. Pub. Health **38**: 664–669. 1948.

Whipple, G. C. Microscopy of drinking water. 1927.

Utilization Abstracts

Castor Oil. "The castor oil molecule has a unique and versatile character that enables the chemist to alter it easily to make it a useful, desirable, and even essential item. Unlike other oils, when castor oil is placed under a vacuum and heated in the presence of a catalyst, it gives up a molecule of water, creating what the chemist refers to as 'conjugated double bonds'. Oil thus treated is used in making decorative and protective coatings, which include paints, varnishes, and lacquers; the oil, or its derivatives, are used in plastics, rayon, nylon, asphalt floor tile, rubber insulations, fungicides, rubber products, soaps, imitation leather, and lubricants. One major castor oil producer sells 185 products made from castor beans and has about 100 other products in the development stage".

"The Korean war has increased demands from defense agencies for castor oil, since it is used in jet-engine lubricating oil and other aircraft lubricants, hydraulic fluids, military all-purpose grease, and plastic-coated combat wire. In addition, castor oil is used as a plasticizer in the manufacture of military fabrics and explosives and for other war purposes".

"Practically all the raw beans used in the United States have come from Brazil, Manchuria, Africa, and India. These sources, which could never be considered certain, have fallen short of meeting even present needs, let alone possible future requirements. Present production of castor oil is approximately 150,000,000 pounds, which does not satisfy the demand. U. S. production in 1951 was placed at a mere 20,849,011 pounds of hulled beans, which undoubtedly amounted to less than 10,000,000 pounds of oil. Estimates on the land area necessary to satisfy anticipated needs range from 100,000 to 1,500,000 acres, depending on the nature of the areas and the cost of production".

The above-mentioned domestic production has been achieved in the Antelope, Imperial, Pale Verde and San Joaquin Valleys of California, in the Salt River and Yuma Valleys of Arizona and in a dozen towns of Oklahoma and Texas.

"In 1951 a program for domestic production and procurement of castor beans on 90,000–100,000 acres was authorized by the Department of Agriculture at the request of the Munitions Board. This program, carried out by the Commodity Credit Corporation, was made available to farmers, who entered into contracts with the CCC, or with private companies under contract with CCC, in areas in Oklahoma, Texas, California, and Arizona for which adapted seed was available. The price to be paid these farmers was to be 10 cents per pound or the market price at time of delivery, whichever was the higher.

The CCC entered into contracts with manufacturers for the purchase of needed equipment and contracted for purchase of available seed for sale to farmers. Plans for 1951 called for planting about 27,000 acres of irrigated land in Arizona and California, 3000 acres of irrigated land in Oklahoma, and 60,000 acres of dry land in Oklahoma and Texas. A goal of 78,000,000 pounds of castor beans was expected to produce 34,000,000 pounds of oil, plus a seed supply for 1952, but only 20,849,011 pounds of beans were harvested from 62,735 acres.

In November 1951 the Secretary of Agriculture announced an identical castor bean program for 1952—based, however, on 200,000 acres, of which 56,000 is to be irrigated and the remainder dry land. Production goals are set at 113,000,000–155,000,000 pounds of beans, from which 50,000,000–70,000,000 pounds of oil would be obtained. Whereas three-fourths of 1951 production was from California and Arizona, the greater part of the 1952 crop is expected to come from Oklahoma and Texas". (W. E. McIntyre, *Sci. Mon. 75: 42. 1952*).

Useful Algae. A brief but excellent article under this title summarizes the economic importance of these plants from the statement that the amount of photosynthesis carried on by them in the oceans of the world is about ten times as much as is performed by land plants to the specific uses of algin in stabilizing ice cream. (F. J. Weiss, *Sci. Am. 187(6): 15–17. 1952*).

Brazilian Tannins. These and their vegetable sources, most of which are unexploited commercially, are:

ACACIA NEGRA. From bark of *Acacia decurrens* var. *mollissima*, containing a maximum of tannin, 36% to 40%, when the trees are three to four years old. Cultivated mostly in the States of Rio Grande do Sul and Santa Catalina, but also in the State of São Paulo.

ANGICO. From the bark of *Piptadenia rigida*, containing 15% to 20% tannin. The wood is sometimes also used as a source of tannin. Extract is produced only in the State of Paraiba.

APERTARUAO. From leaves of *Piper aduncum* with about 9% tannin.

BARBATIMAO. From bark of *Stryphnodendron barbatimao*, containing 22% to 27% tannin; the fruit shells contain about 27%, the wood about 14%, but they are not generally used for leather tanning. This is the most used and best Brazilian extract, and exploitation of young forests is already on an industrial scale. Cutting takes place every three years in autumn.

CAPOROROCA. From the bark of *Rapanea ferruginea*, containing about 10% tannin.

GOIABEIRA. From the bark of *Psidium guaiava*, containing about 15% tannin.

JATOBA. From bark of *Hymenaea stilbocarpa*, 19% tannin.

MANGUE. From leaves and bark of *Rhizophora*, *Avicennia*, *Laguncularia* and *Cassipourea*. These grow chiefly in the coastal region from Para to Rio Grande do Sul and in river valleys and on lake banks in Amazonas. The tanneries of Santos, São Paulo, and environs consume about 1,800 cubic meters of bark and 1,350,000 kilos of leaves annually. The tanneries in Santa Catarina get their tannins almost exclusively from the leaves of mangua trees and have a yearly consumption of about 400,000 kilos.

MURICI. From bark of *Byrsonima verbascifolia* with about 20% tannin.

QUEBRACHO. From the wood of *Schinopsis Lorentzii* which, because of its great hardness, is used for other purposes also. Grows mostly in Mato Grosso, and modern tanning extract plants are near the Parana River. Trees 100 to 200 years old are used. Liquors with about 7% tannins are obtained in the copper extractors, subsequently evaporated to 35% to 50% concentration, and the final solid extract contains about 60% tannin.

SIBIPIRUNA. From the wood of *Caesalpinia tinctoria*, about 15% tannin.

(E. Belavsky and E. Termignoni, *Jour. Am. Leather Chem. Assoc. 47: 594–603. 1952*).

India's Gur Industry. The modern cane-sugar factories of India, which are equipped with up-to-date machinery and turn out about 1,960,000 short tons of the white product every year, have been able to buy only 20% to 27% of the annual cane crop from the 3,645,000 acres of cane land in the country. The rest of the sugar consumed in India is produced by innumerable small primitive mills, using various modifications of ancient techniques, with some modern adaptations, and producing as much as or more sugar than all the planters of Hawaii, Puerto Rico and Australia put together. Such crude native sugar of India is known as "gur".

After the juice is boiled in open pans and the skum skimmed off, a clarifying agent is added, and for this purpose certain plant extracts are preferred. The best is a water extract of deola (*Hibiscus ficulneus*); next in preference is an extract prepared from the dried bark of sukhlai (*Kydia calycina*).

"Sugar is produced in India not only from sugar cane but also from several species of palm trees, of which the most important is the palmyra palm (*Borassus flabellifer*). There are millions of these trees in Madras, Bombay, Hyderabad, Mysore, Bengal and Bihar; they yield a juice rich in sucrose from which a sugar called "jaggery" may be obtained. This jaggery has a pleasant flavour and commands a higher price than sugar cane gur. Production is estimated at 190,000 short tons; the jaggery industry is therefore of relatively much more importance than the comparable maple sugar industry in the United States". (O. W. Wilcox, *Sugar 47(8): 31. 1952*).

Essential Oils from Evergreen Trees. Only four coniferous evergreen trees of North America contain enough commercially valu-

able oil in their branches and needles to make industrial extraction of the oil profitable—white cedar (*Thuja occidentalis*), black spruce (*Picea Mariana*), hemlock (*Tsuga canadensis*) and Canada balsam (*Abies balsamea*). The amount of oil contained in and obtainable from these species depends on many factors:

"Most oil is obtained from January to March and another peak yield occurs in September and October. The lowest yields prevail in June, July and August, reaching the lowest point generally in July". "During the summer months it is important that the material be distilled without prolonged storage. However, branches cut in winter may be stored in the open for even a few months, without loss of yield or quality of the oils".

"Trees on high ground, growing perhaps also in rocky soil, produce more oil than those which grow in low, sheltered spots. Trees in low-lying swamps and growing close together give particularly poor results. A cold climate appears to contribute to a higher yield and better oil. It is generally accepted that needles collected from young trees produce more oil than those from old trees. This is undoubtedly the case with white cedar. In the case of balsam fir, however, we have found repeatedly that needles from old trees would yield nearly twice as much oil as the needles from young trees".

The oil is obtained by steam distillation of the leaves and of finely cut branches, and the yield greatly depends on the distilling technique and on the construction of the still. (Jules Saman, *Am. Perf. & Ess. Oil Rev. 60: 19. 1952*).

Chlorophyll in Dentifrices. Chlorophyll, obtained first from spinach and later from alfalfa by extraction in ethyl alcohol and filtration, was incorporated in a mouthwash and sold as such 50 years ago in a part of France; it was still in local use less than 20 years ago. In the late twenties another European manufacturer produced a similar product. Both became best-sellers. "These two products had a wholesome residual flavor and a strong deodorizing action which outlasted the masking action of the essential oils they contained".

In 1932 the deodorizing and wound-healing effects of chlorophyll were announced for the first time in Switzerland. "Most probably, chlorophyll acted as both a deodorizing agent, a catalytic stimulant of the growth of normal cells and phagocytosis, and also had a slight bacteriostatic action against such micro-organisms as *Staphylococcus aureus* and *S. hemolyticus*".

The latest of subsequent investigations on the subject was a test on 50 subjects, leading to the following conclusion in reference to the data obtained: "These results are based on close to 1,000 odor measurements made with the osmometer on both types of tooth paste. They demonstrate the superiority of the chlorophyll dentifrice over the plain dentifrice of the same formula, containing insoluble sodium metaphosphate as a polishing agent, in ability to remove and retard the development of mouth odors". (L. C. Barail, *Am. Perf. & Ess. Oil Rev. 60: 23. 1952*).

Nova Scotia Seaweed Survey. The Nova Scotia Research Foundation has been making an extensive survey of seaweed resources along the shores of that Province that are of potential commercial importance, and a preliminary report has been published, covering the southwest shore of Shelburne and Yarmouth Counties. In 1950 nearly eight million pounds of Irish moss were harvested in this area. The potential supply consists of three types of algae, namely, fucoids, or rockweeds, principally *Ascophyllum nodosum*, secondly *Fucus vesiculosus;* kelps, principally *Laminaria longicruris;* and Irish moss, consisting of both the true Irish moss (*Chondrus chrispus*) and the so-called false Irish moss (*Gigartina stellata*). Algae of several other genera are associated with these predominating forms. "The estimated tonnage of harvestable rockweeds in the Yarmouth-Shelburne survey area is 200,000 tons, occurring on 140 miles (43%) of the 325 miles surveyed. In Scotland, 180,000 tons are found on 540 miles (12%) of the 4250 miles of coast surveyed. It is seen, therefore, that not only do the Nova Scotia rockweeds occur in greater density, but in a wider belt, and on a greater percentage of the shoreline .... The Scottish Islands have 38,000 acres of Laminaria beds with 1,200,000 tons. The area surveyed in Yarmouth-Shelburne has 12,000 acres of beds with 900,000 tons". (Constance MacFarlane, *Canad. Jour. Bot. 30: 78. 1952*).

BOOK REVIEWS

American Woods. Shelley E. Schoonover. x + 250 pages. Watling & Co., Santa Monica, Cal. 1951. $7.50.

The brief paragraph on industrial uses which constitutes part of the description of every kind of wood considered in this beautifully illustrated and attractively composed book is but one of the features that render it a valuable contribution to the non-technical literature on the subject. The author, after more than 30 years experience with the U. S. Forest Service, is a wood-working hobbyist, and throughout the book he betrays keen interest in the 150 kinds of wood described, in their workability and their adaptability to various specific purposes. In addition to the many excellent full-page and part-page black-and-white photographs, there are eight pages with two dozen colored plates of as many kinds of wood grain, as well as an introductory chapter on wood in general, a selected list of references on the subject and a list of dealers in wood on whom the home craftsman may call for specific kinds in which to indulge his hobby.

The critical reader may be annoyed by certain inappropriate expressions in the book, which, it is hoped, will be corrected in a second printing. It is implied, for instance, that the word "gymnosperm" is synonymous with the word "conifers", which it is not. Conifers constitute only one group of gymnosperms; the others are ginkgo, the gnetums and all the cycads. Elsewhere one reads that a widely known oleo-resin, Canada Balsam, is "made" from balsam fir. This oleo-resin is not "made" from fir; the tree produces and furnishes the resin, just as a cow produces and furnishes milk, and both products may later be processed by man, but to imply that they are "made" by him is decidedly unfit. Thirdly, it is appropriate that "Chinese sumac" be listed as one of the common names of *Ailanthus*, but to give that name unwarranted authenticity by stating that ailanthus is "a sumac", a term correctly applied only to members of the genus *Rhus*, is again inappropriate. Scarcely any book in its first edition is wholly free from inaccurate trivialities of this nature, and attention is drawn to them not in any spirit of disparagement but solely with the intent of seeing an otherwise beautifully executed publication still better in a later printing.

Plants, Man and Life. Edgar Anderson. 245 pages. Little, Brown and Co. 1952. $4.

Economic botany, in the broadest sense of the term involves much more than a description of industrial plant-utilizing processes and a recitation of the characteristics of various plants that render them economically important. It is concerned also with the origins of such plants, not only in a geographical sense but, as well, in a biological sense; that is, it wants to know how they originally came to be as they are, and whether they arose in the dim and distant past as mutations, as hybrids, as polyploids or in some other manner. Questions of this type enter the field of genetics, and it is therefore not at all surprising but, on the contrary, rather gratifying, to find that one of the foremost present day plant geneticists has temporarily laid aside his purely technical studies in the field and has prepared this somewhat philosophical survey of the subject.

Taxonomists—the botanists who devote their lives to classifying plants on the basis of morphological features regarded as showing phylogenetic relationships—were the first to study economically important plants, but the complexities of the subject have long since induced those investigators to regard these plants as outside their province. This is a situation which Dr. Anderson greatly bemoans, not so much because taxonomists have not studied economic plants but primarily because there have been occasions when they have declined to collect such plants or have even discarded them after collecting. This disdain for cultivated plants, in the opinion of the author, has resulted in a regrettable paucity of knowledge concern-

ing the fundamental nature of cultivated plants, and it remains for the geneticists, the ethnologists, the archaeologists, and particularly for scholars who can combine all these disciplines, to remedy this situation. Factors beyond the control of individual scientists are also responsible, and in summarizing the problem at one point in his book, Dr. Anderson states:

"The greatest difficulty is the fundamental one already apparent to a few of us, that the biological side of the problem is only one side. It is quite as much a problem in history, in archaeology, in anthropology, in nutrition, in sociology. It is difficult to find men or groups of men who can and will work effectively in several of these fields at once. Problems which fall straight across departmental and divisional lines run into administrative red tape. A whole series of coherent, fundamental questions are neglected because they do not fall clearly within the domain of any single discipline".

Elsewhere in the book the author discusses more particularly those economic plants which have especially held his attention, not so much with respect to their utilization as regarding their biological make-up. As a whole, the volume is not a treatise on any one subject but, instead, is a recording of the author's thoughts on a variety of topics related to economically important plants. For the person interested in such plants it serves best by providing reading on certain aspects of the subject that are apt to be overlooked if one's attention is devoted exclusively to the materialistic phases of economic botany.

The Mighty Leaf—Tobacco Through the Centuries. Jerome E. Brooks. x + 361 pages. Little, Brown and Co. 1952. $5.

Some of the most entertaining reading in the entire field of plant utilization is that which is concerned with narcotic plants, for it deals with the behavior of human beings, not as rational creatures but as emotional animals. In the Old World opium is predominant on this score; in the New World, tobacco. The literature on both is enormous, and that on tobacco has been brought together by George Arents in a famous collection housed in the New York Public Library. From 1937 to 1943 an encyclopedic four-volume study by Jerome E. Brooks and based on this collection was published, dealing with the subject particularly before the year 1800. In the present volume the same author has provided delightful reading of the entire tobacco story from the very beginning, October 12, 1492, when tobacco was first seen by Europeans at San Salvador in the Bahamas, to the year 1950 when U. S. Internal Revenue stamps were purchased for more than 360 billion small cigarettes and for 745,060 large cigarettes. The intervening period was devoid of the ruthlessness that characterized the exploitation of lumber and rubber, but it was replete with incidents nonetheless revealing of human behavior in the development of new resources.

Three-quarters of Mr. Brooks' book is devoted to the history of this development from an economic, industrial and social viewpoint; about one-quarter to tobacco as a plant and to the technique of growing it. In the former the reader learns about the prices paid for the weed in Colonial days, about prejudices against it and laws governing its production, about medicinal virtues attributed to it and about the impact of the machine age in the twentieth century upon the growing and marketing of tobacco. In the second part he learns that only two of 50 or more known species of tobacco have been exploited, that tobacco contains the poisonous alkaloid, nicotine, as well as a poisonous essential oil, and that various other plant products must be added to it to produce a product that annually sells in the hundreds of billions of units.

Other aspects of the tobacco story related in the book—from paying 120 pounds of best leaf in Colonial Virginia for a wife to making insecticides from discarded stems—are too numerous to justify further selection of parts to illustrate the extensive historical coverage included, and it would seem sufficient to state that anyone at all interested in the role of plants in man's economy can ill afford to overlook this volume.